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The Manufacture and Properties of Glass and their Application to Illuminating Engineering

THE paper read by Dr. English on the above subject at the meeting of the Illuminating Engineering Society on March 13th proved to be a most valuable and instructive one, and led to an excellent discussion. It is, we believe, the first time that a paper dealing with this subject has been delivered before the society, though naturally the qualities of illuminating glassware have been touched upon incidentally in many discussions on general problems of illumination. The whole question of the manufacture and properties of glass is one of absorbing interest to illuminating engineers. Glass forms the chief material used for the control and direction of light, whether in the form of globes and reflectors used for ordinary purposes of illumination or the lenses and mirrors applied in special cases for projection. Hitherto, as Dr. English remarked, the available literature on this subject has been somewhat scattered and meagre. A paper reviewing some of the chief problems in glass manufacture as related to illuminating engineering was therefore timely.

The first section of the paper dealt with transparency and colour of glass. The dominant impression left on one's mind is the complexity of the many factors influencing manufacture, and the great care that has to be exercised in order to secure constancy and accuracy. Of special interest is the effect of a minute iron content, giving a slight green coloration. The initial coloration can be neutralized by the addition of a decolorizing agent such as manganese oxide, but in course of time glass so treated tends to assume a purple coloration under the influence of light. The ideal step is therefore to exclude iron oxide almost completely from the glass. The feat recorded by Dr. English of reducing this element to less than 0.02 per cent. was regarded by those present as a remarkable one. (The care that is necessary to achieve this object is illustrated by the fact that the mere transport of materials used in glass manufacture on a lengthy railway journey is apt to result in contamination with iron!) This question is of special importance in connection with the production of colourless clear glass. But it may also have some bearing on the manufacture of coloured glasses, for instance those used for artificial daylight units, which Dr. English also discussed in some detail.

Another section of the paper dealt with diffusing glasses and the theory of the scattering effect of the suspended particles. Dr. English's discussion of this matter gave some insight into the difficulties of standardization, and served to explain the diversity in optical qualities found in "opal" and kindred types of diffusing glassware. Not only does one find marked differences in transmission but also a tendency to coloration in some cases, as, for instance, when the filament shines through as a red image surrounded by scattered white light. It is one of the chief advantages of etched and frosted glassware that the scattering effect is apparently secured without any appreciable tendency to selective coloration. On the other hand, one cannot by this method reach the degree of diffusing power as is attained with glass of the opal variety, though etching has proved extremely useful in certain cases —for example in the case of the internally frosted lamps now so widely used.

Consideration of the behaviour of such glassware leads us to refer to another problem—the framing of a definition of "diffusing power." It is singular that whilst illuminating engineers have quite a clear idea of what is meant by this term it has hitherto proved difficult to frame any satisfactory definition. The absence of such a definition in the B.E.S.A. Specification for Illuminating Glassware was commented upon in our summary of the specification in the March issue of this journal. The difficulty, we think, arises chiefly in the attempt to deal with this quantity numerically and the consciousness that, in order to be effective, any such attempt must facilitate easy photometric tests.

The final section of Dr. English's paper dealt briefly with the manufacture of prismatic glassware, which likewise presents many interesting problems. Messrs. Holophane Ltd., have made a special study. As the effect of such glassware depends essentially on the action of transparent glass prisms, accuracy in manufacture is of great importance, and it is also obvious that any appreciable coloration, such as might escape notice in the case of "opal" or kindred cloudy varieties of glass, is here of special consequence.

There are, of course, other important properties of glass, such as heat-resisting power, which were necessarily excluded from the scope of this matter. On these topics something further may perhaps be said on another occasion.

Illumination and Productive Power

IN view of the interest now being taken in the relation between illumination and production, a series of researches summarized by Mr. Arthur A. Brainerd in the *Electrical World* deserves study. Mr. Brainerd emphasizes a point previously raised by him—that mere increase in intensity of illumination is not sufficient unless other defects, such as glare, incorrect shadow conditions, etc., are remedied. He believes that, from the standpoint of production, the usual intensities of 1 to 5 foot-candles are unduly low. But a series of experiments extending over a period of nearly two years suggests that there is little justification for using intensities of illumination higher than 12 to 20 foot-candles. It will be noted that the latter figure is in close accordance with the value found necessary by the Illumination Research Committee for the full efficiency of typesetting by hand.

Assuming, however, that the conditions of lighting are greatly improved in all respects, can one predict with any certainty the influence of these better conditions on production? It would obviously be a great advantage if, besides insisting on the general beneficial effect of better lighting on production, illuminating engineers could predetermine beforehand what the effect on any particular process is likely to be. Such predictions might prevent possible disappointment. In practice, owing to the varying demand of different processes, the increased production may not always prove very striking. In one case mentioned by the author, an increased cost of lighting equivalent to 12½ per cent. on the pay roll led to only 15 per cent. increase in production.

Owing to the complexity of the many factors to be considered, the problem seems very difficult—some might say impossible. Mr. Brainerd, however, suggests a basis of prediction, using a formula in which the effects of the various possible improvements in lighting (intensity, uniformity, greater freedom from glare, etc.) are weighed, and the nature of the work, illustrated mainly in the visual angle of objects viewed and nature of the background, is taken into consideration. The formula derived is stated to have given quite useful results, though necessarily based on various rather arbitrary assumptions. It is also thought that this method of analysis might reveal the prospective advantage of one system of lighting in preference to another. Thus it is suggested that in the case mentioned above, where the increase in production was but small, better results as regards *quality* of work might have been obtained by installing indirect lighting.

One fundamental point which certainly needs to be considered is, what exactly is meant by "improved production"? Increased output is not always the sole criterion. In some industries higher quality of work might be very much more valuable, and it does not follow that the lighting conditions which favoured the one would also be the best for the other.

Finally, it is well to bear in mind that the advantages of a greater output from a manufacturer's standpoint depend very much on his success in marketing his product. If a factory, owing to slack demand, is working at only a fraction of its full capacity, expenditure on lighting with a view to quickening production may not make a strong appeal. In such a case it might be more fruitful to be able to show that the better lighting would lead to enhanced quality of work, thus adding to the prestige of the concern and stimulating demand.

The Limitations of Photometry

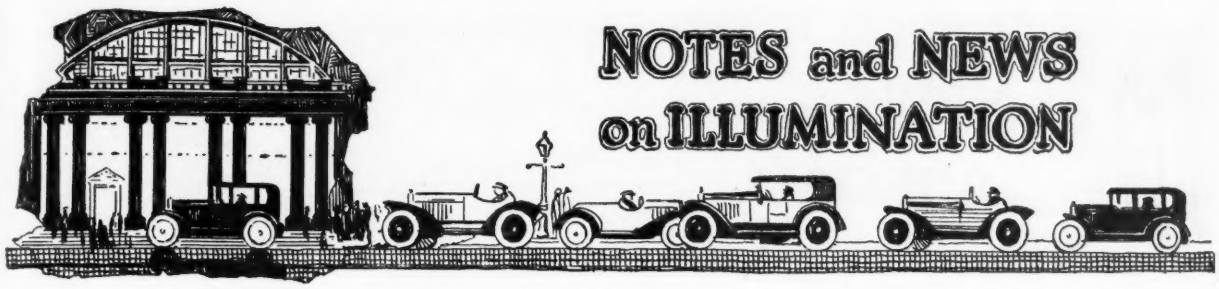
IN his introductory address at the annual meeting of the Lichttechnische Gesellschaft in Karlsruhe last year, which is now reproduced in *Licht und Lampe*, Professor Teichmüller drew a striking picture of the limitations of illuminating engineering on the physiological and psychological sides. We have now attained quite a high degree of precision in the definition and measurement of light on a physical basis. The whole art of illuminating engineering has been rendered possible by the aid of photometric instruments. The great services rendered by photometry to the cause of better lighting can scarcely be overestimated.

Yet, after all, as Professor Teichmüller pointed out, in a photometric measurement the eye only plays the part of a measuring instrument in a "null method"—it resembles the galvanometer applied to a Wheatstone bridge. The eye can perceive with fair exactitude when two immediately adjacent surfaces are of equal brightness. But it can only do so very approximately when the surfaces are far apart—still less can it determine by the mere inspection of two objects *how much* brighter is one than the other. In this respect vision is in line with the other senses. Thus by touching two objects in succession we can determine which is the hotter, but we cannot say how much hotter. We can affirm that the scent of one flower is stronger than that of another, but we cannot say with confidence that it is twice or three times as strong. And when, as in heterochromatic photometry, we have to deal with light of different colours the comparison, even by the "null method," becomes most difficult—just as we should find it almost impossible to compare the scents of, say, roses and paraffin.

The natural consequence of this limitation is that photometry, whilst giving a fairly accurate impression of illumination in a physical sense, may fail to register the *subjective* illumination effect (the actual sense of brightness received by the retina and conveyed to the brain). It is here that the presence of glare and contrast becomes so confusing. Assuming that equality of illumination is attained with two lighting systems, we cannot readily determine how and why one enables us to see better than another, and how much better. For many years illuminating engineers have lacked a ready test of the influence on "seeing power" of glare, though we recall an ingenious contrivance instrument, contrived by Mr. A. W. Beuttel, based on binocular vision, which was intended to separate physical from subjective brightness.

"Glare" is a term that is used somewhat vaguely. It is often spoken of as an effect inseparable from visual discomfort. Yet there are many conditions of lighting which, without causing actual discomfort to the eye, impair its "seeing power," which depends so largely on effects of contrast.

When we come to consider psychological effects of light we find ourselves amidst factors which are still less clearly understood. Some methods of lighting are conducive to increased mental activity, others are sedative. Such effects may play a material part in relation to the effect of illumination on productive power, yet we have little knowledge how to estimate them. It is only recently that attention has been devoted to this new field. Its importance will doubtless be more fuly realized in the future. Meantime, the existence of these phenomena affords one reason why illuminating engineering differs radically from most other fields of engineering. The ultimate judgment of the work of the illuminating engineer must be based on an appeal to the senses.



Lighting Arrangements at the G.P.O.

On Wednesday, March 28th, a number of members of the Council of the Illuminating Engineering Society paid a visit to the G.P.O., on the kind invitation of Major Gunton. The party was necessarily limited to 20, and the invitation was therefore confined to the Council and to members of the Factory Lighting Committee of the National Illumination Committee, for whom the lighting arrangements were of special interest. In the course of their inspection of King Edward Buildings the lighting of the sorting offices and the adjacent telegraph department was examined, the illumination in most cases being of the order of 3–4 foot-candles distributed from overhead reflectors, usually of the semi-indirect or totally enclosed type. Apart from the study of the lighting conditions, the processes of letter sorting and the dispatching of telegrams by the aid of a ramifying tube system, etc., were witnessed with much interest. The party had also an opportunity of descending to one of the underground stations of the post-office tube railway. Here the whole process is of great technical interest, the arrival of the small carriages (which carry only mails and no attendant) being quite uncanny. Particularly fascinating is the control room, where the progress of these little trains can be traced by means of an ingenious luminous diagram. Previous to the visit most of the members of the party dined together at the Manchester Hotel, and it was quite a pleasant gathering. At the conclusion of the visit a warm vote of thanks was expressed to Major Gunton by the President (Mr. D. R. Wilson). Later in the evening several members of the Committee also visited the Osram Lamp Factory of the G.E.C., at Hammersmith, with the object of seeing the overhead lighting, yielding approximately 10 foot-candles, there in use.

Association of Public Lighting Engineers

FORTHCOMING CONFERENCE AT SHEFFIELD, JULY 9TH–12TH.

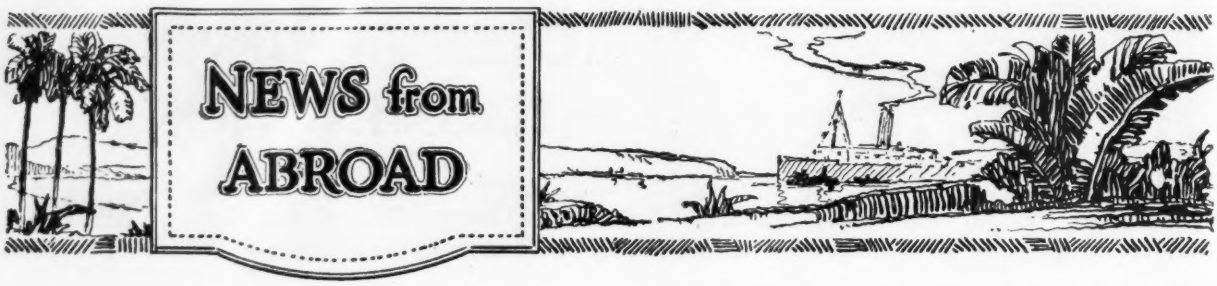
Attention is drawn to the forthcoming Conference on Public Lighting, which is to be held this year during July 9th to 12th. The conference held in Brighton last September was generally considered a most successful one. We understand that on this occasion the gathering has been arranged in July so as to precede the departure of delegates to the International Conference on Illumination in the United States. Members and delegates to the Conference on Public Lighting will be received by the Lord Mayor of Sheffield, supported by the Chairman and members of the Lighting Committee of that city. In addition to the address by the incoming President (Mr. J. F. Colquhoun, Lighting Engineer to the city of Sheffield), papers will be read dealing with various important problems in public lighting. Subjects already announced include "Non-manual Control of Public Gas and Electric Lighting" (Messrs. E. H. Horstmann and E. E. Sharp), "What the Public Want from a Street Lighting Department" (Councillor F. Thraves, Chairman of the Watch Committee; City of Sheffield), and "Visibility" (Mr. J. M. Waldram). It is also hoped to have several practical demonstrations of street lighting embodying the requirements of the British Standard Specification for Street Lighting. Fuller particulars will be obtainable in due course from the Secretary, Captain W. J. Liberty, 68, Victoria St., London, S.W.1.

Luminous Signs as an Aid to Public Lighting

One of the most important changes affecting public lighting of shopping areas during recent years has been the more general adoption of "after-hours" lighting. Whereas a few years ago there were only isolated examples of show windows kept alight after hours of custom, one can now see long series of windows so lighted. From the standpoint of the merchant this is one of the cheapest forms of publicity; from the standpoint of the public the extra lighting of the street is welcome. The light emerging from such windows is mainly reflected and diffused, and free from objection from the standpoint of glare. Even more important than the actual illumination received by the roadway and pavement, which is not high, is the relief afforded by the general brightening of the background to street lamps. One of the great drawbacks of public lighting hitherto has been the fact that lamps are necessarily spaced far apart, and are seen against a background of obscurity. This naturally accentuates any tendency to glare, whilst the fact of light being received from a few directions only gives rise to troublesome shadows. Another useful addition to public lighting is afforded by illuminated signs, provided designers show reasonable restraint in regard to brilliancy. As an instance it is only necessary to recall the flood of light received from the illuminated signs outside the Tivoli Theatre, in the Strand, which produce an illumination on the roadway probably much in excess of that furnished by the public lamps. Light from large signs of this description has the merit of coming from a multitude of bright points, so that shadows are soft. But, with a view to avoidance of glare, the use of internally frosted or obscured lamps is desirable; whilst signs which embody violent flashing devices cannot be regarded as helpful to public lighting, which should above all be *steady*.

Artificial Sunlight Treatment

It is satisfactory to observe that the complexities of artificial sunlight treatment continue to receive attention from the medical profession. The problem is an intricate one. Added to the physiological complexities —for many diseases are being treated, and no two cases are quite alike—are the variations arising from the physical differences in the lamps applied. Many different lamps have been introduced. Apart from the main distinction between arc lamps and mercury-vapour lamps, yielding widely different spectra, infinite variations are possible in arc lamps, according to the types of carbons (solid carbon, tungsten, tungsten-cored, nickel-cored, etc.) used. We notice in *The Medical Officer* a useful contribution from Dr. James Johnstone summarizing his own experience in supervising a light clinic. His experience with arc lamps seems to favour the use of a white-flame positive carbon with a solid negative. On the whole he confirms the belief expressed by others that the carbon arc lamp is best adapted for general treatment, the mercury-vapour lamp being reserved for local treatment in which powerful exposures of short-wave radiation are desirable. For many purposes the longer exposure required with a carbon arc is a safeguard, and the mercury-vapour lamp should only be used by a skilled and experienced operator.



Another Lighting Journal

We have received the first three issues of yet another journal dealing with lighting, *Lux* (*La Revue de l'Eclairage*), which is being published in Paris under the editorship of Monsieur J. Wetzel. The first number contains an introductory article by Monsieur Paul Janet, who describes a course of lectures on various aspects of photometry and illumination which is being established at the Ecole Superieure d'Electricité. M. Mallet-Stevens deals with the architectural aspects of illumination, and describes a somewhat novel arrangement—a double "artificial window" mounted in the corner of the room. Examples of cornice lighting, etc., are also presented. There are some novel illustrations of shop-window lighting—one highly ingenious display being the showing of a film depicting the anxiety of a lady in search of a suitable present for her husband, suitable objects in the window being meantime "picked out" by spotlights as the story progresses. Subsequent issues, a leading feature of which is a series of contributions by M. H. Desacres, describing the lighting of Paris, are equally interesting. It is only a short time since we referred to the publication of *L'Eclairage* in Brussels. The simultaneous appearance of a new journal dealing with illumination in Paris is an indication of the spread of illuminating engineering abroad.

The Influence of Temperature on the Transmission of Coloured Glasses

A recent contribution by Mr. M. Luckiesh to *The Electrical World* indicates that the influence of temperature on the amount of light transmitted by coloured media is much greater than is commonly assumed. Experiments conducted some years ago showed that a deep red glass transmitted at 350°C. only 42 per cent. of the light transmitted at room temperature; the transmission of cobalt glass, on the other hand, increased by 8 per cent. These results are of interest in connection with photometry, and especially the study of the transmission of coloured media used with incandescent lamps. Experiments with coloured caps used with an ordinary 150-watt lamp showed that constancy of transmission was only attained at the end of about 20 minutes after the lamp was switched on. During this period the transmission of the red decreased by 41 per cent., the yellow by 9 per cent., and the green by 16 per cent., whereas the blue had increased by 3 per cent. This would seem to be a point that should be kept in mind in dealing with glass used with artificial daylight units, though, as such glass is mainly blue in tint, the change here may be expected to be relatively small.

Illuminating Engineering in Japan

The latest issue of the *Journal* of the Illuminating Engineering Society in Japan contains, amongst other items, a contribution by Mr. E. Ogawa dealing with the street-lighting situation in Japan. This is in Japanese, but there are a number of interesting illustrations from which it appears that diffusing lanterns, similar to those adopted in many American cities, are becoming very popular in Japan. The chief item in this issue, however, is a very full account in English of the work of the International Commission on Illumination and the proceedings at the meeting in Bellagio.

Acetylene Lighting in France

The acetylene industry in France is very skilfully organized, and one frequently observes in the *Journal de l'Acetylene* information on recent developments. One interesting point is the manner in which the demand for acetylene lighting has altered during recent years. The amount of carbide used for lighting purposes, 20,000 tons, is slightly less than that consumed for this purpose in pre-war days. What has altered is the nature of the lighting. Prior to the war, at least three-quarters of the consumption of 25,000 tons was devoted to standard acetylene installations for lighting buildings. But with the widespread development of electric lighting there has been an inevitable tendency for this form of acetylene lighting to diminish. At the present time it accounts for little more than a quarter of the total amount of carbide consumed for purposes illumination. The remaining three-quarters is used for special purposes, e.g., portable lamps, "flares," motor-car headlights, etc. The significant fact is the enterprise with which these other applications of acetylene have been developed so as to make good the diminution in ordinary lighting installations.

Electric Lighting in Italy

A correspondent of *Electrical Industries* refers to the proposal to establish a representative committee in Italy to enquire into the position of the electric lamp manufacturing industry in that country. In view of the natural growth in electric lighting there should be ample opportunities for lamp factories. But apparently manufacturers find it hard to compete with the imported article. The correspondent of *Electrical Industries* also gives some interesting particulars of methods of electric lighting in Italy. Apparently few private houses are well equipped with wall sockets for portable lamps, and, generally speaking, there is need for methods giving better diffusion of light and "soft" effects. The method of grouping a cluster of lamps as a central unit—which is regarded as obsolescent in this country—is still in frequent use. Imitation chandeliers, with electric lamps simulating candle-flames, are also popular, and whilst the decorative effect is good in some cases the arrangement is not a very efficient one. In view of the fact that electricity is used for lighting almost universally, and is found in even the smallest villages in Italy, there should be very good opportunities for developing the most modern systems. Owing to the fact that Italy has to rely on imported coal, hydro-electric stations have been developed on a large scale, and the number is stated to have increased from 276 in 1920 to over 700 at the present time.

The Distribution of Illumination in Space

A novel method of appraising lighting installations was described by Dr. W. Arndt in a recent paper read before the Illuminating Engineering Society in Germany.* He considers the method of measuring illumination on a horizontal plane inadequate, and proposes instead to measure "lumens per cubic cm." by means of a special photometer terminating in a sphere of opal glass, which replaces the customary plan test-plate. This instrument measures distribution of light in space, and the idea of relating flux of light to cubic capacity of space illuminated is illustrated by several ingenious diagrams.

* *Lichte und Lampe*, April 5th, 1928.

TECHNICAL SECTION

COMPRISING

Transactions of The Illuminating Engineering Society and Special Articles

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

The Manufacture and Properties of Glass and their Application in Illuminating Engineering

By S. ENGLISH, D.Sc., F.I.C., F.Inst.P.

(Paper read at the Meeting of the Illuminating Engineering Society, held in the Holophane Lecture Theatre, Elverton Street, Westminster, S.W.1., at 6-30 p.m., on Tuesday, March 13th, 1928.)

THE work of the illuminating engineer may be said to be the efficient production of light and its distribution in the most effective manner, having regard to both the technical and artistic points of view. In the carrying out of these twin objectives glass is found to be one of the most frequently used materials; in fact it may be said that glass is probably the most important tool that the illuminating engineer has at his disposal, whether he is considering natural illumination or artificial illumination, using gas or electricity. It is somewhat strange then to find in books on illuminating engineering that the subject of glass and its properties is very seldom mentioned, and, even if mentioned at all, it is dismissed in a very few words, and with no attempt to deal with it at all adequately. In going through technical literature a similar dearth of information is found; this is perhaps because until comparatively recently the scientific investigation of the properties of glass and their application to various uses has been carried on only by a few commercial firms who were not in the habit of publishing the results of their investigations. This state of affairs fortunately exists no longer, for we now have research institutions specially devoted to the investigation of technical glass problems both in this country, in Germany, and in the United States. Some commercial laboratories are also showing a disposition to place on record in the technical journals results of their researches which are of general interest. This is all to the advantage of the illuminating engineer, but unfortunately this information is very scattered, and is therefore not easily available, except to those who have access to a good technical library. It is the object of the present paper to bring together some of this information in the hope that, when collected and sifted, a summary of it may be of interest and some use to illuminating engineers. Of course, it will readily be understood that a full discussion of the manufacture and properties of all kinds of glass used by illuminating engineers and architects is not possible in one short paper; the manufacture of electric lamp bulbs provides in itself more than sufficient matter for one paper, while, if natural lighting be considered, it would be difficult to deal satisfactorily with the manufacture and properties of sheet glasses in one paper. For this reason only such properties as affect general lighting glassware are considered in the present paper.

Transparency and Colour of Glass.—The main reason why glass is used for illuminating purposes is that it has the power of permitting light to pass through it. If a particular sample of glass transmits freely all the various colours which go to make up white light without any selective absorption, it appears, and is said to be colourless, but even the most perfect glass, as used in precise optical instruments, always absorbs a small proportion of the light passing through it. The absorption for the best qualities of European optical glass is generally between 0.3 and 0.6 per cent. of the incident light per centimetre length of path.

Glasses of this quality are never met with in ordinary illumination work, and consequently the absorption of light by illuminating glassware, even when clear, is much higher than the figures just quoted. In this connection the data given in the D.S.I.R. Illumination Research Paper No. 2, on the transmission of light through window glass, is of interest. In this report it is shown that when a collimated beam of light is incident normally on the surface of polished plate-glass it transmits 90 per cent. of the light. Assuming the accuracy of Fresnel's formula, between 8 and 8.5 per cent. of the lost light is accounted for by reflection at the two surfaces of the glass plate, thus leaving from 1.5 to 2 per cent. presumably lost by absorption in the glass itself, the thickness of which was $\frac{1}{4}$ inch. Absorptions approaching this value should be expected in ordinary clear illuminating glassware.

When glasses are coloured they contain as one of their constituents either a metal which gives a coloured silicate or material separated in a very finely divided or colloidal state. For example, when iron is present in glass it generally gives a green or blue-green colour, due to ferrous silicate; cobalt, as cobalt silicate, gives the well-known deep-blue glass; while gold, copper and selenium in the finely divided metallic form (i.e., colloidal) give various shades of red. Of the numerous glass-colouring oxides only one, namely, iron oxide, is ordinarily found (in appreciable quantities) in the raw materials from which glass is made. This accounts for the green colour which is usually found in cheap glassware. In better qualities of glass (except optical glass) this green colour is apparently removed from the glass; but actually it is only neutralized, or covered up, by adding to the glass mixture some material or materials which give a colour to the glass complementary to the iron green. For ordinary illuminating glassware, these materials are manganese dioxide and arsenious oxide; the arsenious oxide modifies the iron-green colour somewhat, and the manganese produces a complementary purple tint.

Fig. 1 shows curves B and C, illustrating the absorption of glasses coloured by iron oxide and by manganese dioxide. It is obvious that a decolorized glass containing both these constituents must have a general absorption throughout the spectrum, and consequently must absorb more light than the undecolorized glass, which has only a selective absorption. In the case of glasses melted in tank furnaces selenium and arsenious oxide are now generally used for decolorizing purposes. With the care which is now given to the production of decolorized glass very

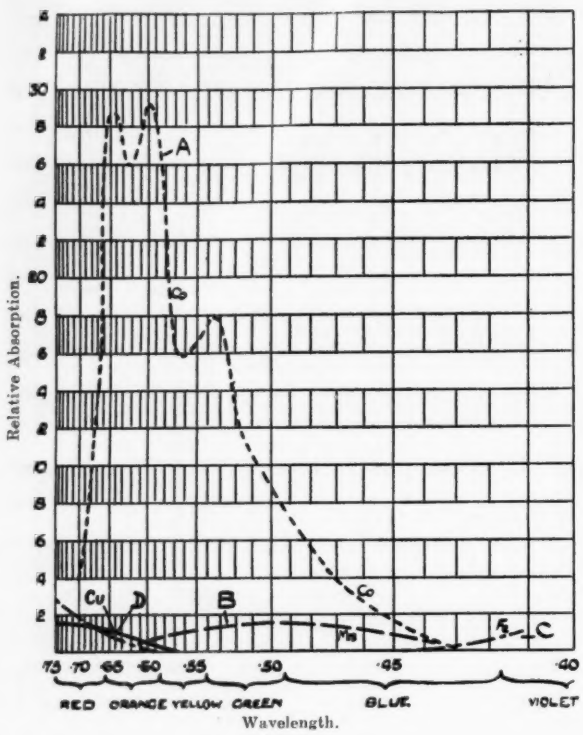


FIG. 1.

satisfactory results are generally obtained, but even perfectly decolorized glasses are liable to cause trouble to the illuminating engineer who has occasion to use them in the open air, as, for example, in street lighting units. The trouble referred to is the development of colour in the glass during service even though when installed it showed no trace of colour. Ships' lenses and pavement lights are perhaps the best examples of this change of colour; as one walks along the streets of London numerous purple-coloured pavement glasses may be seen. Windows and roof lights also often show the same defect, but they are less noticeable. A sample of glass which was recently taken from a station roof after being in service for 80 years was found to be a very deep purple colour although no doubt it was colourless or even pale green when placed in position. This change in colour of glass is always found to be more pronounced in districts and locations that receive a plentiful supply of sunshine, and is no doubt due to the chemically powerful ultra-violet rays found in direct sunlight. It is now well known that ultra-violet rays, such as are found near the lower limit of the sun's spectrum —which is generally placed at .295μ (μ= .001 mm.)— promote oxidation, and ordinary manganese decolorized glasses contain two colouring oxides which are generally, to a certain extent, in a reduced condition owing to the action of the glass-furnace atmosphere. These two materials are the lower oxides of iron and manganese, and if sufficient manganese is incorporated in the glass to neutralize the colour given by the iron oxide (ferrous) then a decolorized glass is obtained, but when such a glass is subjected to the oxidizing action of the ultra-violet rays some of the iron oxide appears to be altered to a higher state of oxidation (ferric) which is not such a powerful colouring agent, also some of the manganese (which had been partly reduced by the furnace atmosphere) is reconverted into the fully oxidized form. Both these changes destroy the balance of colour which was obtained by the glassmaker, with the result that the manganese purple colour is developed in the glass. This colour development may take months or even years when the glass is exposed to the sun's light, but it may be accelerated by exposing a decolorized glass to the action of the very short ultra-violet rays given off by a quartz mercury-vapour lamp. With a good lamp half an hour is generally sufficient to show some change in colour.

It has been claimed in a 1927 French patent specification that the incorporation of lead oxide up to 3 per cent., or titania up to 2 per cent., in a glass prevents the redevelopment of colour in pavement lights, etc., when exposed to sunlight. Montgomery, in an American patent specification (1923), claims that the incorporation of antimony oxide in a glass is effective in preventing discoloration on exposure to sunlight. Attempts have also been made to overcome this trouble by using a decolorizer of another type, namely, selenium, but unfortunately it was not successful, for on prolonged exposure to sunlight such glasses developed a distinct yellow colour. This development of colour in selenium decolorized glasses by exposure to sunlight has also been noted by Cousen and Turner (J.S.G.T., 1925, ix, 111).

This trouble with the redevelopment of colour in glass by strong sunlight led the firm with which I am now connected to discard decolorizers altogether in their glasses which are designed for use in exposed places, e.g., street-lighting refractors, but even this extreme course was not in itself completely satisfactory, as under the action of prolonged bright sunlight a suggestion of a yellow colour developed. This was no doubt due to the oxidation of the iron present in the glass to the ferric state. The only perfectly satisfactory solution appears to lie in the manufacture of such units from glass containing no iron oxide at all, and at the present time we have attained the extraordinarily low iron oxide content of about 0.02 per cent. An alternative explanation of the development of colour in glass by short-wave radiations has recently been put forward by Sir Herbert Jackson (*Nature*, 1927, pp. 120, 264 and 301), who suggests that the colours are due to very finely divided particles separating from solution in the glass, but a discussion of the merits of these hypotheses is outside the scope of the present paper.

The whole question of the colouring of glass is of very great interest, but only one more phase of it can be considered here. To the illuminating engineer the question of light filters to produce definite coloured effects is a matter of some importance. This is especially the case in the production of so-called artificial daylight. It is well known that the light given from a gasfilled electric lamp has not the same quantitative combination of colours as are found in the light given by the sun. It is obvious to anyone that electric lamp light is warm yellow when compared with sunlight, due to a preponderance of red and yellow rays. This is shown diagrammatically in Fig. 2, the curves in which represent the energy distribution of the light from (*a*) an electric lamp, (*b*) the sun.

In order to produce the effect of daylight from an electric lamp it is usual to pass the light through a glass filter, which allows the shorter wavelengths—violet, blue and green—to pass freely, while abstracting the

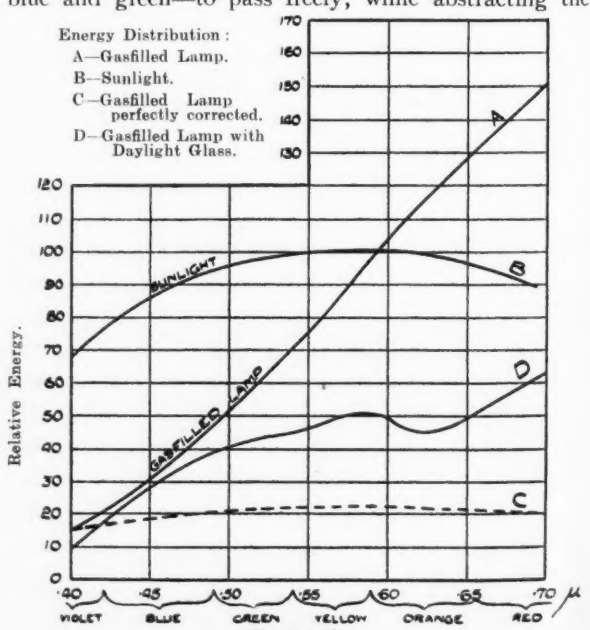


FIG. 2.

undesired proportion of the yellow and red rays. For this purpose simple cobalt-blue glasses are unsuitable, as they absorb too much of the green light and pass far too much of the red rays. Fig. 1 shows the absorption curve, A, of a cobalt glass (one part of cobalt oxide to 1,000 parts of glass) which shows distinctly the asborption in the orange, yellow and green regions and the transmission in the blue and red ends of the spectrum. To overcome this difficulty daylight filters are generally made of glasses containing both cobalt oxide and copper oxide, the latter oxide in the cupric condition producing in glass a weak blue-green colour. The absorption curve for this oxide (two parts copper oxide to 100 parts of glass) is shown as D in Fig. 1, from which it is clear that glasses containing this oxide transmit freely green and blue rays, but absorb red rays. By a proper combination of these two oxides, then, it is possible to obtain a glass which filters out the excessive red, orange and yellow rays of an electric lamp in the proper proportions to produce a light approaching daylight in quality.

Fig. 2, B and D, shows the relative energy in various parts of the spectrum of sunlight and of light from an electric lamp after passing through such a coloured filter. It will be noticed that the corrected light is deficient in blue and contains too much red, but even so it is better than that given by some so-called daylight lamps. Orr (*The Illuminating Engineer*, 1923, 16, 167) found in one electric daylight lamp an excess of red of between 300 and 400 per cent. When it is remembered that cobalt oxide is an exceedingly strong colouring agent and that only one part of this oxide is used in about 10,000 parts of glass in the production of glass for daylight lamps, and that the thickness of the glass itself also affects the colour, it is easy to realize that in the production of colour-filters of this type on a commercial scale it is almost impossible to guarantee absolute uniformity in the absorption properties of different samples. Some authorities have recommended using other colouring oxides as well as those of cobalt and copper, e.g., Luckiesh and Dewey (U.S.A. patent 1920, No. 1,331,937) recommend the use of a glass made with the following proportions of colouring oxides to 1,000 lbs. of sand: manganese dioxide, 2 parts; cupric oxide, 3.8 parts; and cobalt oxide, 0.18 parts. Also Lamplough has a British patent covering the use of gold in addition to copper and one of the following metals, cobalt, nickel or manganese, in the preparation of "daylight" glass. Instead of being incorporated in the same glass the gold may be present in a separate sheet. Other authors have suggested the use of iron oxide (ferrous and ferric), but it appears unwise to introduce such oxides, as we have already seen that they are liable to change their state of oxidation while in use, and any such change would cause a change in the colour-correcting power of the glass. In fact it has been reported to the writer that "daylight" glass of a well-known make has been found to change colour in use, thereby losing its colour-correcting value. One other point of interest arises from a consideration of Fig. 2. It is obvious that compared with sunlight the light from an electric lamp is very deficient in the "blue" wavelengths, and if a correction is to be obtained by filtering the light, it can only be done by reducing the intensity of the other colours, thus rendering the lamp very inefficient, as shown in curve C. In general, the better the correction, the worse the efficiency.

Diffusing Glasses.—One of the most noticeable features in modern illuminating engineering is the strong tendency to eliminate the glare of bare lamp filaments. This is much more necessary now than it was before gasfilled lamps were introduced. There are three principal methods of avoiding the possibility of seeing bare filaments, and each of them consists in causing an enclosing globe or envelope to act as a virtual source of light of much less intrinsic brightness than the filament itself. These three methods consist in the use of (1) opal glass, (2) etched or sandblasted glass and (3) glass with a prismatic or irregular surface. Though the illuminating effects of these three are somewhat similar their properties as glasses are so very different that they must be treated separately.

Opal Glass.—In the study of opal glasses it is necessary to remember that ordinary glass is in all probability a mutual solution of various silicates and silica, and that this complex solution has not solidified as metals do, but has remained in the true liquid condition; on cooling it has gradually become stiffer and stiffer until complete rigidity has set in. Just as solutions of ordinary liquids when hot may be saturated and on cooling become super-saturated, with the consequent separation of some of the material in solution, so glasses may also become super-saturated with respect to certain constituents, and if conditions are suitable these particular constituents separate from the clear glass and cause it to become cloudy, or opalescent, or opal. A large number of substances have at various times been used in the manufacture of opal glass, the chief being fluorides, chlorides, sulphates, phosphates, alumina, zinc oxide and tin oxide. Often two or more of these materials are used in the same glass. For example, the chief opalizing agent in use at the present time is cryolite (Na_3 Al F_6), a material containing both alumina and fluorine. When glasses containing these constituents are melted they are perfectly clear, indicating that all the materials are actually in solution in the glass at the melting temperature, which may be in the neighbourhood of 1,300°–1,350° C., but on working such glasses the falling temperature causes the separation of a second phase. The actual material which separates out has been the subject of many speculations, but in the case of fluoride opals the matter appears to have been satisfactorily settled by Ryde and Yates (J.S.G.T., 1926, 10, 274), who, by using the X-ray method of crystal analysis, have shown that the material which separates out from the clear glass in ordinary opals consists of a mixture of sodium and calcium fluorides. Schott (*Licht und Lampe*, 1925, 1 and 2, and *Glas. Tech. Ber.*, 1925, 315) has also shown that in phosphate opals the separations are small spheres, presumably of calcium phosphate. The action of opal glasses in diffusing may be somewhat different in some fluoride and phosphate opals, for the fluoride separations are sometimes in the form of very minute crystals, while the phosphate separations are always in the form of very small transparent spheres which have a different refractive index from the body of the glass. As one result of this difference Schott claims that "transparent sphere" opals, such as the Jena Milch glass, absorb much less light than ordinary opals, and quotes the following table:

TABLE 1.

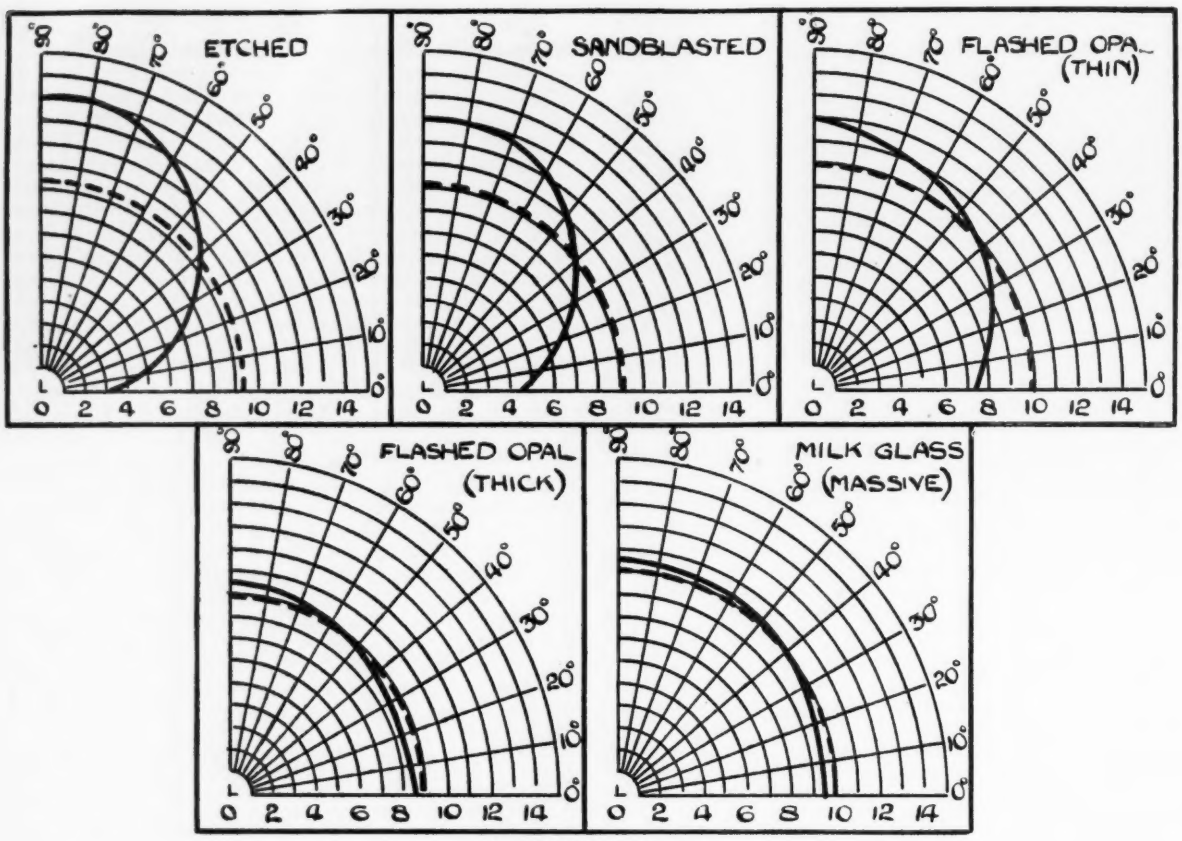
Percentage of light absorbed by various glasses.

	per cent. absorbed
Clear glass	5.5
Etched ,, ...	7.5
Sand blasted	11.2
Flashed opal (thin)	9.3
,, ,, (thick)	11.5
,, ,, showing red glow ...	27.0
Jena milk glass (massive 2 mm.) ...	19.5

Polar diagrams, showing the diffusion of light on passing through five of these glasses, are shown in Fig. 3, and it is worthy of note that the "Milk" glass gives quite as good, or even better, diffusion than the thick flashed glass although its absorption is distinctly less. Schott suggests that the quality of a light-diffusing glass should be measured by the ratio of the scattering power to the absorption, i.e.,

$$\text{Efficiency} = \frac{\text{Scattering power}}{\text{Absorption}}$$

The breaking up and diffusion of a beam of monochromatic light by a piece of opal glass depends upon three factors: (1) the amount of material separated from solution in the glass, (2) the size of the particles of this separated material and (3) the difference in the refractive indices of the glass and the separated material. It is easily understood that if only a very small quantity of material is separated from solution light will pass through the glass more or less as a continuous beam with only a small fraction of it diffused, but as the amount separated in a suitable form increases so the percentage of light passing straight through decreases and more light is diffused; at the same time more light is reflected. Passing on to a consideration of the second



Light Distribution Curves.
FIG. 3.

factor it must be remembered that for a particle to be able to affect a ray of monochromatic light the particle must have a definite minimum size, the actual value of this minimum being approximately the same as the wavelength of the light considered. It follows from this that an opal glass may be prepared which contains a normal proportion of separated material with a very small particle size. Such a glass would be effective in scattering the short wavelengths light, blue and green, but might not affect the longer wavelengths, orange and red. In such a case, if an electric lamp were viewed through the opal, the red and orange lights, not being diffused but passing straight through the glass as a continuous straight beam, would show up the filament as an orange-red glow. On the other hand the diffused light would have a blue tint. A glass of this type reported on by Schulz gave a direct transmission of 70 per cent. for red light and only 20 per cent. for blue light. Such opal glasses were quite common a few years ago, but recent work on the mechanism of the process of separation of particles from glass has led to a certain amount of control over both the quantity of the second phase separating and the size of the particles so formed.

Success in this matter involves the control of—

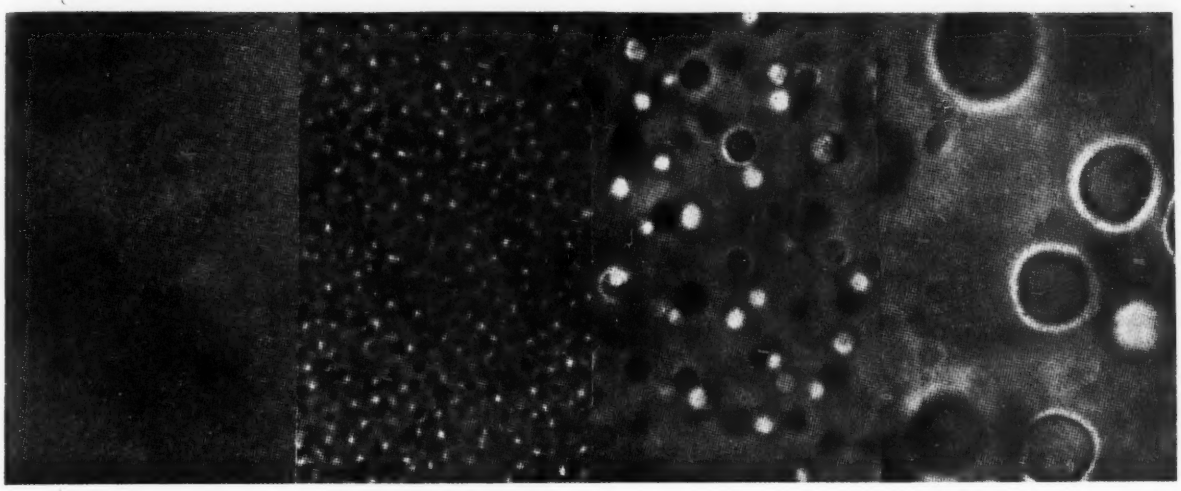
(1) The amount of opalizing material in the glass when it is melted ready for working, which is not the same as the amount included in the raw materials.

(2) The temperature of working and the rate of cooling during working.

(3) The obtaining of a suitable viscosity in the glass at the temperature at which separation takes place in order to allow the particles to grow to the desired size. Of these various factors the second, namely, the temperature of working and the rate of cooling, is most important, and unfortunately is most liable to vary unless the operations involved are under scientific or other strict control. This often leads to opal glasses showing marked irregularities which used to be looked upon as unavoidable. To show the effect of heat treatment on opal glass Hyslop (J.S.G.T., 1927, 11, 362) took a melt of a normal opal glass and quenched it by pouring into water so as to retain the glass in a transparent condition by preventing the separation of any fluorides from solution. Granules of the clear glass were then placed in crucibles and heated to various temperatures for five hours. After this treatment sections were prepared from the middle of the mass of glass and microscopic examinations gave the average particle diameter in the various samples as below:—

Temperature of reheating	*Particle diameter (average)* (μ = .001 mm.)
700° C.	0.17μ
800° C.	0.33μ
900° C.	1.00μ
1,000° C.	3.00μ

At these temperatures the particles were spherical in shape, but at higher temperatures (1,000° C. and 1,200° C.) they again became smaller and assumed definite angular crystalline shapes. Fig. 4 is a composite reproduction of photomicrographs showing the relative sizes and shapes of the particles produced in this experimental investigation. Although Hyslop does not mention the fact, it is probable that the glass reheated at 700° was only opalescent and had a bluish tint. If so it would be quite useless as a diffusing glass, while that heated to 800° and having particles of an average diameter of .33μ—rather less than the wavelength of the shortest visible ray—would no doubt show a lamp filament as a sharp red line while diffusing the blue light more or less satisfactorily. The glass heated to 900° with particles of an average diameter of 1.0μ—i.e., longer than the wavelength of the longest visible red ray—would no doubt have satisfactory light-diffusing properties. Another most important matter appears to have been satisfactorily explained by this same research recently published by Hyslop. Besides the variability of the diffusing properties of opal glasses many people have noticed that occasionally opal glassware is extremely brittle, the slightest knock being sufficient to cause fracture. Gehloff (J.S.G.T., 1927, 11, 347) showed that brittleness could be induced in opal glass by working it from the furnace below a certain critical temperature, i.e., the temperature at which separation of the second phase began, but Hyslop carried this further and showed that the brittleness was due to the formation in the glass of sharp angular crystals as distinct from the spheres shown in Fig. 4.



× 3000 C. Heat treated at 700°. × 3000 C. Heat treated at 800°. × 3000 C. Heat treated at 900°. × 3000 C. Heat treated at 1000°.

FIG. 4.

The presence of dendritic crystals in an opal glass which was found to be very brittle is shown in the photomicrograph reproduced in Fig. 5. It is clear from these details that the production of a perfectly satisfactory opal glass is a very difficult matter, but it is equally clear that the glass industry, both here and in Germany, is working energetically towards that end and a comparison of present-day opals with those of twenty years ago shows that a great deal of progress in that direction has already been made.

Frosted Glass.—Another method of reducing the intense brightness of modern electric lamps lies in the use of what may, in general, be termed frosted glassware. One particular application of this frosted-glass—namely, the pearl lamp—has recently sprung into prominence, and at the moment it appears probable that it will to a large extent displace the opal lamp bulb, because of its much less light absorption factor. The pearl-finished lamp is said to have a surface brightness of only about 1/100 of that of a bare filament. The frosting of glass may be accomplished by chemical or mechanical means, i.e., by the use of etching liquids such as mixtures of hydrofluoric acid (HF), ammonium fluoride (NH_4F), potassium fluoride (KF), and sodium fluoride (Na F), or by sand-blasting, which consists in bombarding the surface of the glass by angular grains of sand propelled by a stream of compressed air. The light-diffusing action of such glass therefore differs from that of opal glass in so far as the whole of the diffusion takes place on passing through the irregular surface, and not in the body of the glass itself. Since this surface is produced in the cold, the process can be manipulated so as to obtain any desired degree of irregularity from a smooth semi-polish to the coarsest matt that can be desired; and, further, by adhering to standardized conditions, uniformity of results can be relied upon, so that any degree of diffusion that is required can be obtained and maintained without much difficulty. Frosted glasses also enjoy one further advantage when compared with opal glasses, namely, they diffuse light of all wavelengths equally, so that no matter whether the frosting be heavy or light the filament of a lamp never shows up as a red glow—if it is visible at all it shows up its natural colour. Since the diffusion of light on passing through frosted glass takes place only at the roughened surface, it appears natural that for a given diffusing power such a glass would have a less light absorption than an opal glass. This is confirmed by reference to Table 2, in which Schott gives the absorption of acid-etched glass as only 7.5 per cent. Other investigators have worked on this problem, and have brought out the interesting and not unexpected fact that the percentage transmission of frosted glass is greater when the rough side faces the source of light than when the direction of the light is reversed. Luckiesh (*Journal, Franklin Institute*, 1918, *185*, 551; and *186*, 529), after discussing the chief factors determining the nature and degree of the reflection of light from a surface gives the following data for the transmission factor of various light-diffusing glasses:—

Specimen of Glass.	Side towards light source.	Transmission Factor. Narrow Beam.	Diffuse Light.
Sand blasted ...	Rough	0.783	0.702
	Smooth	0.739	0.695
Etched	Rough	0.794	0.709
	Smooth	0.758	0.704
Coarse ribbed ...	Ribbed	0.766	0.617
	Smooth	0.515	0.616
Fine ribbed ...	Ribbed	0.858	0.793
	Smooth	0.790	0.791

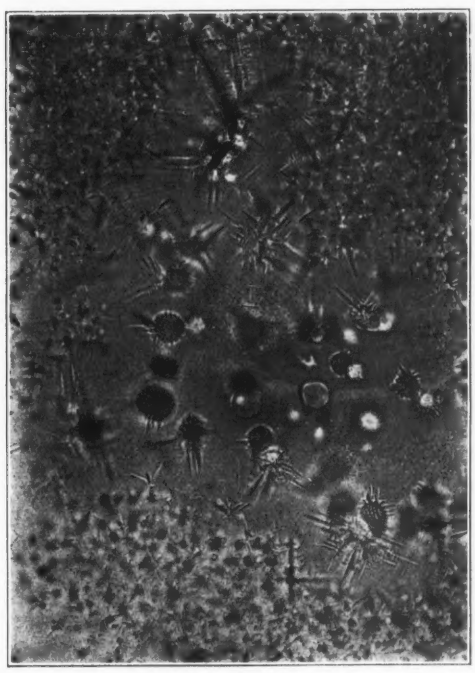


FIG. 5.
Opal Glass showing dendritic crystals.

In every case a better light transmission was obtained when the rough side of the glass faced the light source. This was particularly noticeable when a narrow beam of light was being passed through coarse-ribbed glass, the decrease in transmission being more than 30 per cent. of the higher value.

Polar curves showing the light-diffusing power of a sand-blasted glass and an acid-etched glass are reproduced in Fig. 3. They both show fairly good diffusing power, except in directions nearly parallel with the

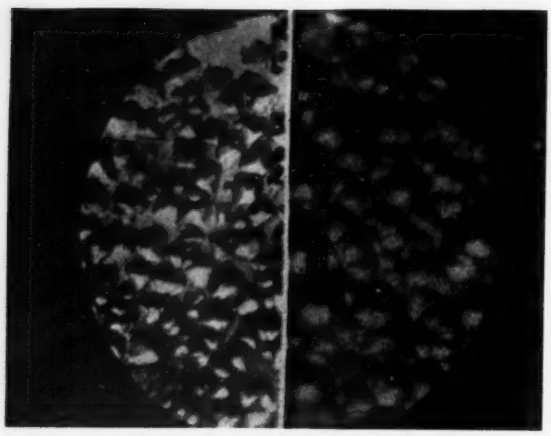


FIG. 6A.

FIG. 6B.

surface of the plate under investigation, but they are neither of them so efficient in this respect as the opal glasses.

The method of producing the pearl lamp is interesting and brings out one or two characteristics of acid-etched glasses; it is therefore worthy of being followed in a little detail. The etching of lamps on the outside of the bulb has been known for a long time, but such lamps suffer from the fact that the etched surface is rather rough and difficult to keep perfectly clean. This roughness is due to the deposition on the surface during the etching process of insoluble fluorides, e.g., lead fluoride, calcium fluoride, barium fluoride, according to the nature of the glass and the etching solution employed. Fig. 6, taken from the previously mentioned paper by Schott, shows photomicrographs of the surfaces of two different glasses after acid etching. In the case of a high resistance glass (*a*) definite crystals are shown, while in the case of an ordinary lime glass (*b*) the crystal structure is not well marked, though it covers the whole of the surface.

To overcome the loss in efficiency caused by the gradual fall in the transparency of outside-frosted bulbs, attempts were made to utilize internal frosting, but such attempts were doomed to failure for a time, since the process of internal etching rendered the bulbs so very brittle that they would not withstand even feeble shocks. Examination of the etched surfaces under a high-power microscope revealed the fact that they were traversed by numerous deep fissures which constituted lines of weakness. Fig. 7A shows a microphotograph of a specimen of glass etched in this way. This peculiar surface structure was no doubt due to the nature of the etching

FIG. 7A.

FIG. 7B.

solution, which was such as to give a very rapid action, only about 20 seconds being allowed for this part of the process. Solutions for producing matt etching generally consist of alkali fluorides with a certain proportion of hydrofluoric acid. The solution used for etching the glass shown in Fig. 7A was no exception to this general rule, and analysed as follows: —

Hydrofluoric acid	...	...	27 per cent.
Ammonium fluoride	...	...	29 ,,
Sodium fluoride	...	...	6 ,,
Water	...	...	37 ,,

In the production of the new pearl lamps the rough matt etch produced by this solution is removed, and the sharp fissures mentioned previously are opened out and rounded by the use of another solution of an acid character and distinctly weaker—containing approximately 26.5 per cent. hydrofluoric acid (HF) and 23 per cent. silico-fluoric acid ($H_2 Si F_6$) and water. A photomicrograph of the surface of a piece of glass, after being smoothed by this fortifying solution, is shown in Fig. 7B, from which it is clear that all the deep fissures have been removed, and the glass is therefore reasonably strong again. The first frosting, fortifying and washing processes are all carried out on one machine, with which one operator can turn out about 63,000 bulbs completely frosted, fortified, washed and dried in eight hours. A diagrammatic sketch of a machine of this type is shown in Fig. 8, in which the tank A contains the frosting solution, B and D contain hot washing water, and C

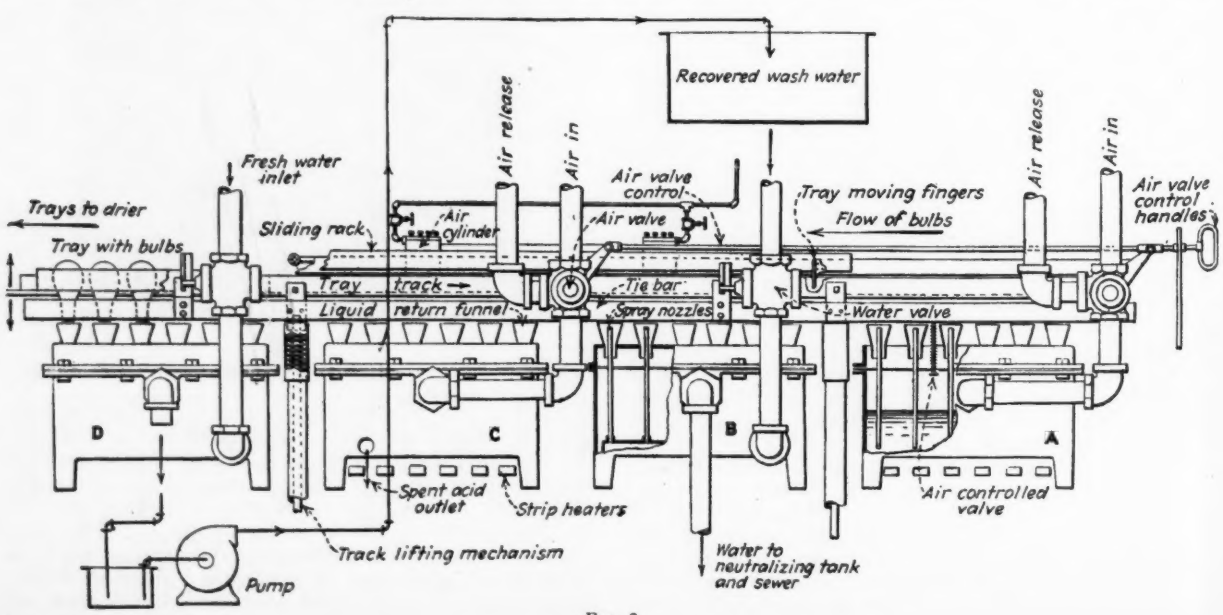


FIG. 8.

Sketch showing in detail a side elevation of the Frosting Machine.

contains the fortifying solution. Lamp bulbs are placed in the funnel-shaped supports in trays and passed by an intermittent motion over the various jets, from which the appropriate liquid is sprayed into them. About 30 seconds are allowed for the filling, spraying and moving on of each tray. It is claimed by Pipkin, the inventor of this process, that the internal frosting of lamp bulbs in this way only causes a reduction in the light emitted of 2 per cent., i.e., about one-third of the average absorption of the outside-frosted bulb. However, Dr. Spate, working in Berlin, gives the absorption of such lamps as between 2.5 and 14 per cent., calculated on the output of the clear lamp, and states that the light scattering varies from 11 to 45 per cent., depending on the strength of the matt surface, as compared with a scattering of approximately 80 per cent. for opal bulbs. An attempt has been made by Percival (British patent 1925) to combine the advantages of inside frosting and opalescence in one lamp bulb.

Refracting Glassware.—Two types of light-diffusing glassware have already been considered; (1) opal glass, depending on the light-scattering action of an emulsion with particles between 0.3 and 2μ in diameter, and (2) surface-roughened glass, the irregularities in the surface of which are larger than the particle size in an opal but still are very small. The third type, to which we now turn, has irregular surfaces of a comparatively coarse nature, and, just as it was seen on passing from opals to matt surface glasses an increase of control over the production was obtained, so again on passing to the type of glass with still larger surface irregularities an increased control is obtained, so much so that it is possible to produce large numbers of such pieces of glass, being perfectly confident that they will all give identical results. One further advantage of dealing with surfaces of an easily controlled size is that they may be designed to redirect light in certain definite directions instead of giving the random distribution which is characteristic of opal and matt glasses. This may be illustrated by a moment's consideration of the front glass of a motor-car headlamp. If an opal glass were used only a limited amount of the light given by the lamp would be transmitted and that would be in a symmetrically diffused manner, while if matt glass were used the transmission would be greater and more light would be thrown forward; at the same time a certain amount of symmetrical diffusion would be produced. However, if a clear glass with vertical flutes is used the maximum possible amount of light is thrown forward and it is spread out in a horizontal direction but not vertically. This is illustrated diagrammatically in Fig. 9. The diffusing of light in this way was first applied to illuminating ware in what is known a Holophane glass, which is so designed as to appear completely luminous. In hiding the actual source of light it acts as a virtual source of much larger dimensions in somewhat the same way as opal glass globes, but without the internal absorption of the latter kind of glass.

Glassware of this type, which depends for its usefulness and efficiency on its being designed according to the laws of optics, is always made of clear glass and is shaped by pressing the molten glass into a specially cut mould by a former or plunger. This plunger must be tapered towards its lowest point, and may have cut in its surface a series of prisms or flutes, but they must lie parallel to the direction of movement of the plunger itself so as to permit of the withdrawal of the former from the pressed glassware. When vertical control of the light is desired, then horizontal prisms on the glass are necessary, and their contours must be cut in the body mould, which, on the completion of the pressing operation, is opened clear of the prismatic glass surface.

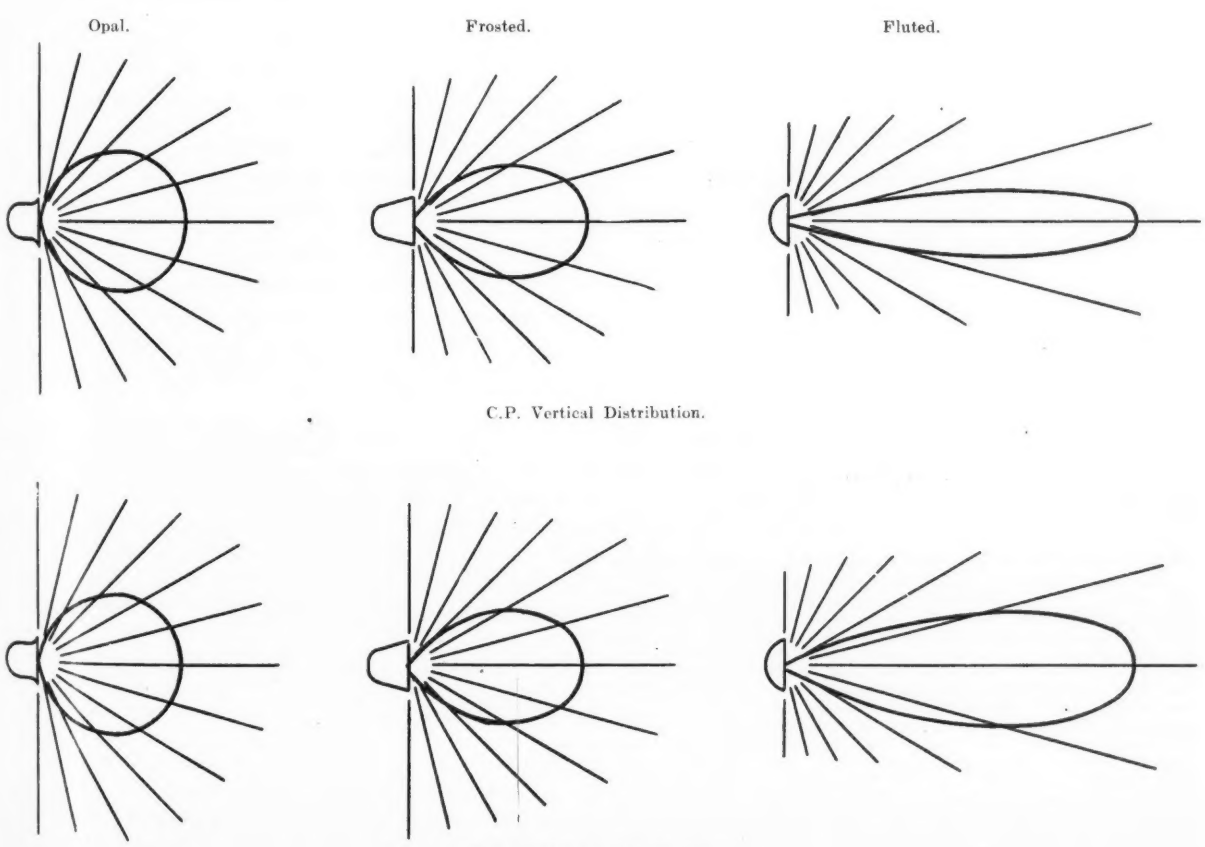


FIG. 9.

Photographs of the plunger for the outer portion and a body mould for the inner portion of a directional street-lighting refractor are shown in Fig. 10.

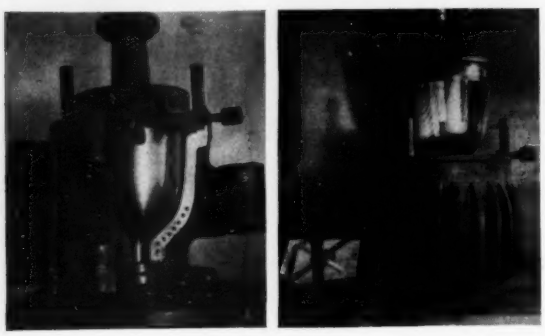


FIG. 10.
Holophane Directional Street Refractor Moulds and Plungers.

To the experienced glass manufacturer there is no difficulty in the manufacture of such pressed glassware. There are difficulties, however, in the design of such glassware, for the designer must calculate the shapes and angles of the prismatic surfaces accurately to give the desired light distribution, which is not the case when working with opal glassware.

(*The discussion on Dr. English's paper and the author's reply will be found on pp.* 151–156.)

ANNUAL MEETING

The Annual Meeting of the Illuminating Engineering Society will be held at the Home Office Industrial Museum at 6 p.m. on Tuesday, May 22nd, when the Annual Report of the Council for the past year will be presented.

In accordance with the Constitution, the list of the present Officers and Members of the Council is presented herewith.

The Council has nominated Mr. C. C. Paterson, O.B.E., Director of the Research Laboratories of the General Electric Co. Ltd. and President of the International Illumination Commission, as President of the Illuminating Engineering Society, in succession to Mr. D. R. Wilson ; and has nominated Dr. John W. Walsh (National Physical Laboratory) a Vice-President of the Society.

It will also be recalled that, following the death of Mr. Gaster on January 7th, Mr. J. S. Dow was nominated as Hon. Secretary.

Honorary Members of Council :—

In accordance with the arrangement entered into by the Council with various scientific, professional and technical bodies, the Presidents of these bodies become Honorary Members of Council during their tenure of office, and their presence is invited at meetings at which subjects of common interest are discussed. These bodies include : The Institution of Gas Engineers, The Institution of Electrical Engineers, The Institution of Municipal and County Engineers, The National Gas Council, The Council of British Ophthalmologists, The Ophthalmological Society, The Physiological Society, The Municipal Electrical Association, The British Electric and Allied Manufacturers' Association, The British Electrical Development Association, The Electric Lamp Manufacturers' Association of Great Britain Ltd., The Electrical Contractors' Association, The Society of British Gas Industries, The Institution of Public Lighting Engineers, The Women's Electrical Association. In addition, the Presidents of the Illuminating Engineering Societies in the United States of America, Germany, Austria, Holland, and Japan are created Vice-Presidents during their tenure of office.

Present Officers and Members of Council

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(Member of the Home Office Departmental Committee on Lighting in Factories and Workshops; Member of the Illumination Branch Committee of the Department of Scientific and Industrial Research; Secretary of the Industrial Fatigue Research Board.)

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Dr. R. LESSING (Consulting Chemist) (1909)
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Mr. HAYDN T. HARRISON (1909)
Mr. W. J. JONES (E.L.M.A.) (1923)

(3) *Makers of Illuminating Apparatus, Lamps, Fittings, etc.:—*
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Mr. C. W. SULLY (E.L.M.A.) (1923)
Mr. J. WYATT IFE (Holophane, Ltd.) (1909)
Mr. H. H. THOMPSON (Holophane, Ltd.) (1927)

(4) *Representing Gas and Elec. Supply Companies and the Consumer respectively :—*
Dr. J. F. CROWLEY (Consulting Engineer) (1912)
Mr. A. CUNNINGTON (Southern Railways) (1912)

(5) *Connected with the Architectural Profession, Surveyors, etc.:—*
Mr. J. DARCH (Surveyor) (1909)
Mr. A. G. PORRI. F.R.I.B.A. (1927)

(6) *Physiologists, Oculists and Ophthalmists, etc.:—*
Dr. A. H. LEVY (Ophthalmic Surgeon) (1910)
Mr. J. B. LAWFORD (Past President of the Ophthalmological Society) (1925)

(7) *Interested in General Physics, Science and Photometry:—(Extended)*
Mr. A. BLOK (1912)
Mr. J. S. DOW (1909)
Mr. J. W. T. WALSH (Nat. Physical Laboratory) (1914)
Mr. C. C. PATERSON (G.E.C. Research Laboratories, Wembley) (1909)
Lt.-Col. C. H. SYLVESTER-EVANS (Air Defence Experimental Establishment) (1919)

(8) *Interested in the supervision of the Illumination of Buildings, Factories, Schools, etc.:—*
Capt. W. J. LIBERTY (1911)
Mr. D. R. WILSON (1910)

Ex-Officio :—

President :—Mr. D. R. WILSON (1910)
Hon. Secretary :—Mr. J. S. DOW (1909)
Hon. Treasurer :—Mr. J. WYATT IFE (1909)

(The numbers in brackets after the names of members of Council indicates the date of election as a member of the Society.)

POPULAR & TRADE SECTION

COMPRISING

Installation Topics—Hygiene and Safety—Data for Contractors—Hints to Consumers

(The matter in this section does not form part of the official Transactions of the Illuminating Engineering Society; and is based on outside contributions.)

E.L.M.A. Seventeenth Illumination Design Course

By all accounts the seventeenth Illumination Design Conference, which commenced at the E.L.M.A. Lighting Service Bureau on April 30th, should prove even more successful than its predecessors. As mentioned in our last issue, the course differs in several respects from the courses previously held, a feature being the efforts made to deal specially with practical problems, and the novel and interesting demonstrations arranged.

The list of discourses mentioned in our last number, which covers such subjects as Light and Visibility, the Lighting of Schools, Offices, Homes, Streets, etc., Floodlighting and Electrical Advertising, is a very attractive one. The field for spectacular and decorative lighting is a particularly promising one, and we are glad to see that the question of " architectural lighting " is amongst those to be discussed.

By the time this issue appears the course will have been launched, but any of those who are interested and have not yet obtained full particulars can do so by applying to the E.L.M.A. Lighting Service Bureau, 15, Savoy Street, Strand, London, W.C.

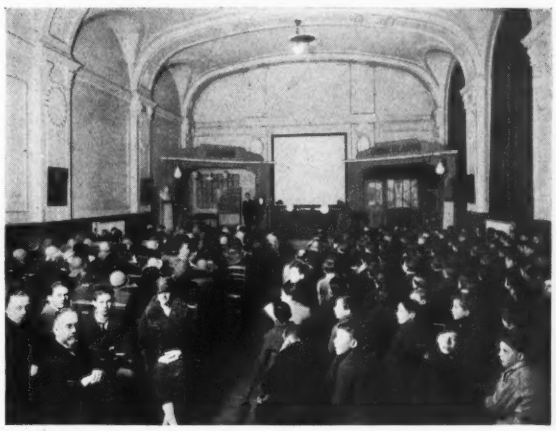
The Electrical Association for Women

The third annual report of the Electrical Association for Women contains evidence of expanding work. The Association is now installed at its new headquarters in Kensington Court, the landlords being the Kensington & Knightsbridge Electric Light Co., and the premises are appropriately equipped with everything requisite in the way of electric lighting, heating, etc.

During the past session there has been a number of interesting lectures and social events, and visits to numerous factories and showrooms have taken place. A special series of lectures was also arranged for the benefit of women engaged in the electrical industries, in most cases either the lecturer or the chairman being women. Lectures have also been given to school teachers at the London Day Training College, to Women's Institutes, the Women Citizens' Association, etc. Arrangements were also made for a party of London schoolgirls to visit the Hackney Power Station, prizes for the three best essays being offered by Mr. L. L. Robinson, the engineer.

Much interest is being taken in the work of the Association overseas. The Irish Free State has already formed an Association on similar lines, and inquiries have been received from Sweden, New Zealand, South America, and other countries.

Lectures on Illumination in Brussels



The above illustration shows the audience at one of the lectures on illumination organized by Messrs. Philips Lamps Ltd., in Belgium, to which reference is made on p. 146. This is a striking instance of enterprise in developing interest in illuminating engineering abroad.

Association of Public Lighting Engineers

FIFTH ANNUAL CONFERENCE IN SHEFFIELD.

With reference to the forthcoming fifth Annual Meeting and Conference, which is to be held in Sheffield in July next, we are informed by the Secretary of the Association of Public Lighting Engineers that the payment by local authorities of the expenses of delegates has been duly sanctioned. A letter received from the Ministry of Health endorses the attendance of two delegates, one of whom should be the engineer or superintendent for public lighting in the district. The payment of reasonable expenses incurred in connection with their attendance is sanctioned in the case of any local authority whose accounts are subject to Government audit.

Individual applications to the Minister for sanction in respect of the conference will not be necessary so long as the proposed expenditure is within the limits indicated.

Electrical Contractors' Conference

The third Annual Conference of the E.C.A. Allied Associations is to be held this year at Cheltenham during July 4th–6th. We notice that the papers include one from Mr. H. Marryat, entitled " Trading without Tears; the E.C.A. Policy."

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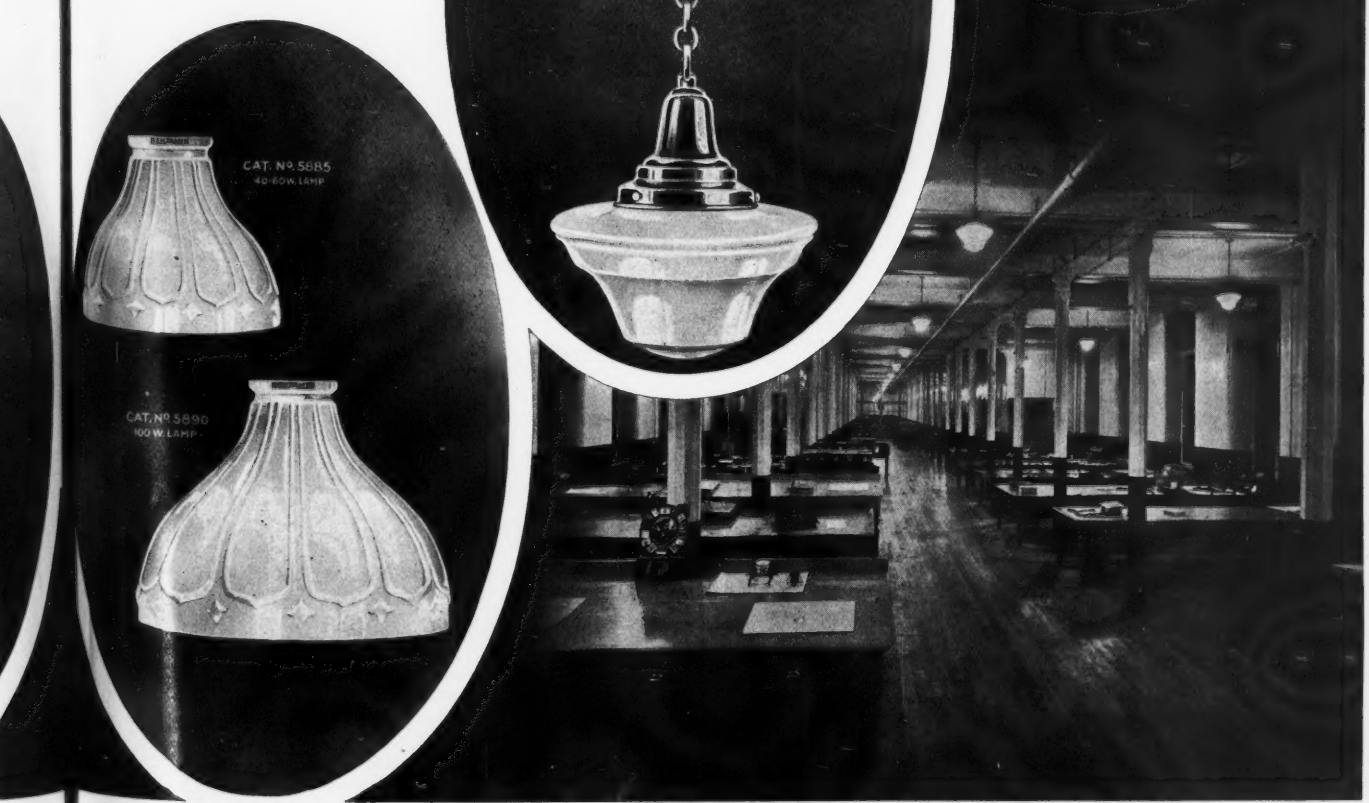

Some Notes on the Lighting of the New Underground Railway in Sydney (New South Wales)

IT will be recalled that in our issue of October, last year, some reference was made to the lighting of the new underground railways in Sydney.

Through the kindness of Mr. A. Turnbull, Lighting Superintendent of the N.S.W. Government Railways, we have received some further particulars of this interesting installation. At present, trains are running on only a portion of the complete railway system, which includes the Central, Museum and St. James stations.

This railway, unlike the London tubes, is close to the surface, and the Quay section will be in the open. The underground sections are being tunnelled, or excavated, in solid ferrous sandstone. The tunnels are lined with cement, which is poured into the forms through holes drilled from the surface, and the method of construction presents interesting features.

FIG. 1.—The Northern Booking Hall just before completion.

The wiring on the stations is carried out in solid-drawn screwed conduit embedded in the concrete. The conduit runs are set out beforehand on scale drawings, and then from these each length of tubing is set out to full-size dimensions on a marking-out floor. In this way the conduits are cut and set to the various shapes required in advance of the concreting. This procedure ensures the steady progress of the structural work without any delays through time taken to set conduits in the forms. Very few draw or junction boxes are used—instead advantage is taken of the lamp positions for drawing and looping the conductors. So far as practicable the lamp positions are set out in squares, and for general lighting calculated on a basis of 4 foot-candles on platforms and in offices.

The tunnels are permanently lighted from 40-watt lamps located on the spring of the arches and spaced at 26-foot centres. These lamps are enclosed in specially designed bulkhead fittings, which give much greater longitudinal and vertical projections than that obtainable with the usual trade design of bulkhead fittings.

The tunnel lighting is only used in connection with the maintenance of the permanent way and overhead catenary equipment; therefore during hours of normal traffic it is not in service.

Central Electric Station.—The platforms are in the open, with semi-underground booking halls and offices. The platforms are lighted from 60-watt gasfilled lamps in Holophane "I" open reflectors. There is nothing of a special nature in this lighting. Fig. 1 shows the Northern booking hall just before completion. The lighting is from specially designed ceiling fixtures fitted with Holophane glassware. These fittings are obscured on the photograph by the ceiling beams.

Museum Station.—As will be seen by reference to Fig. 2, the platform and offices of this station are underground and depend wholly upon artificial lighting for the required illumination. The lighting units consist of Holophane F.150 reflectors and 150-watt gasfilled lamps held in specially designed detachable galleries to facilitate cleaning, and at the same time give greater security than the usual set-screw arrangement. The lighting units are spaced at 15 ft. 4 in. centres, and 14 ft. 7 in. above platform level. Booking and other station offices are provided at both ends of this station. The stairways and barrier sections are lighted with the

FIG. 2.—Museum Station on the new Underground Railway, Sydney.

aid of Holophane 12 refractor reflectors and 150-watt gasfilled lamps in special mountings of Egyptian design. At the street entrances these are further embellished with Holophane cow-bell reflectors pendent from the four corners, each containing a 40-watt lamp. Ceiling fixtures with Holophane 10-inch reflector bowls and 60-watt lamps are used in connection with the lighting of the foot subways and passages on this and the other stations of the system.

St. James Station.—Although the structural work is entirely different the platform lighting arrangement is similar to that provided at the Museum Station; it is probable this will be the method adopted for platform lighting on all the Sydney underground stations. St. James Station, which is also entirely underground, derives its name from an historic church adjacent to the Queens Square entrance. This fact will explain the ecclesiastical character of the lighting fixtures shown in Fig. 3, which illustrates a portion of the concourse at St. James Station. These fixtures were designed to

FIG. 3.—The Concourse at St. James new Underground Station, Sydney.

B T-H LIGHTS

Apart from their lighting merits, B.T.H. enclosing fittings are exceptionally beautiful and dignified in appearance. The glassware itself has a charm rarely, if ever, equalled, and a diffusive quality which transforms the harsh brilliance of a gas-filled lamp into a soft mellow glow.

In the lighting of homes, offices, hotels, stores, etc., these enclosing pendent fittings confer the ultimate touch of beauty and good taste. There is sufficient variety of design, colour, shape and size in this new range of fittings to make possible a selection harmonizing with almost any decorative scheme.

Dust accumulation is minimized by the use of enclosing fittings, and the only attention required is an occasional dusting of the exterior surface.

Enclosing Fitting with "KELDON" (Regd. No. 686359) Glassware.

LIGHTING SERVICE.

The artistic ability of our designers, coupled with the scientific knowledge of our engineers, will be placed at your disposal, without obligation, should you at any time desire our collaboration in specifying equipment for any installation in which you are interested.

The British Thomson-Houston Co., Ltd.,

Mazda House, Newman Street, Oxford Street, London, W.1.

Fittings Factory - - - Lower Hillmorton Road, Rugby.

Branch Office Showrooms : BELFAST—31, Linenhall Street. BIRMINGHAM—10 & 11, Snow Hill. BRISTOL—119, Victoria Street. CARDIFF—26 & 27, St. Mary Street. DUBLIN—25, Suffolk Street. GLASGOW—53, Pitt Street. LEEDS—19a, Wellington Street. LIVERPOOL—16, South Castle Street. MANCHESTER—King's House, King Street West. MIDDLESBROUGH—Post Office Bldgs., Marton Road. NEWCASTLE—Commercial Union Bldgs., Pilgrim Street. SHEFFIELD—Mazda Bldgs., Campo Lane. SWANSEA—7, Melbourne Place.

2955

be used for direct or indirect lighting. In the former case the bottom is fitted with a complete Holophane refractor reflector unit, and when desired for indirect lighting the interior is fitted with an inverted E.150 Holophane open-type reflector; when arranged in this way only the bottom glass of the refractor reflector unit is used to give the required appearance. Each of these fixtures is made up from four brass castings with oxy-welded seams.

The details of the lighting of Wynyard and Town Hall stations are now in the course of preparation.

The accompanying photographs were taken without the aid of any lighting other than the normal illumination provided on the premises. It will be conceded that the complete outline of the reflectors and detail on the fixtures shown on these photographs is evidence of the absence of glare, despite the fact that direct lighting has been employed. The clocks in Fig. 2 bear witness to the shortness of the exposure necessary to produce the photographs with the illumination provided.

In conclusion it may be stated that the Sydney underground railways, although an important section, form only a small part of the lighting work on the New South Wales Railways, which have a connected lighting load apart from train and tram lighting of over 3,000 kilowatts.

The official photographs illustrated in this article have been released on the authority of Mr. W. H. Myers, the Chief Electrical Engineer of the N.S.W. Government Railways, by whose permission we have also received a series of interesting plans illustrating the lay-out of some of these installations.

The Lighting of a Garage

The lighting of garages, which frequently occupy important prominent roadway sites, is well worth attention. The number of people who habitually use their cars by night is continually increasing. If the outside lighting is effective, the existence of the garage becomes fixed in the minds of drivers, who afterwards recall it as a convenient place of call.

The accompanying illustration, for which we are indebted to the courtesy of Messrs. Korting & Mathiesen Electrical Ltd., was taken entirely by the artificial light provided, and illustrates that even a simple installation such as this may present quite a variety of problems. Kandem diffusing units are mounted above the pillars and petrol pumps, and suitable lettering is inscribed on them. The showroom is floodlighted by two 200-watt units in the corners of the room, and the frontage is also floodlighted by similar units, one mounted behind the pillar in the foreground, the other on the side wall.

The garage itself receives general lighting, and good illumination is provided in the waiting-room and private offices.

Lectures on Illumination for School Children

On the Continent lectures to schoolchildren on the subject of lighting, arranged by Messrs. Philips Lamps Ltd., are being followed with great interest. It is generally recognized that the proper use of light is a most important subject, having an important bearing on industry and indirectly on commerce. The experiment of instructing schoolchildren in the elementary principles of light distribution, although only in its initial stages, may possibly lead a change in schools' curriculum.

With the collaboration of the educational officer and municipal authorities of Antwerp, Philips have been able to organize a series of lectures in Antwerp as have already been given by the company in their demonstration rooms at Brussels for several years past. A large hall was placed at their disposal, where the lecturer addressed in 18 sections nearly 6,000 pupils from the municipal schools, aged from 12–20 years. By way of preparation the educational authorities arranged for the teachers to give a special lesson on the subject of the lecture—light—for which Messrs. Philips supplied the necessary material and data.

After having explained and illustrated the elementary construction of the eye, the lecturer proceeded to discuss the essential standards expected from artificial lighting. A collection of lantern slides, consisting almost exclusively of untouched photographs relating to the subject, enabled the lecturer to illustrate clearly his points. Instructive demonstrations were also given from the platform with models of workshops, shop windows, etc. At the conclusion of each lecture a film illustrating the manufacture of electric lamps at Philips Works was shown to the audience.

These lectures have proved such a success that in Antwerp the educational authorities made arrangements whereby they could be extended over a longer period. The municipalities of Ghent and St. Nicholas are making arrangements whereby the schoolchildren of these towns can have the benefit of these interesting lectures, and it is expected that other towns will shortly be following suit.

EVERYTHING The G.E.C. your guarantee ELECTRICAL

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"UNALUX," "SUPERLUX"

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G.E.C. Electric Light Fittings combine skilful and efficient design with the careful application of the highest-class glassware.

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"EQUILUXO" GLASSWARE
Doriclite unit.
Semi-indirect all-glass pendant.

"EQUILUXO."
For semi-indirect lighting in lofty premises, or where a white ceiling is not available. An upper reflector is introduced constructed of similar material to the translucent bowl.

"BRITALUX."
Low-absorption best-quality opal glass. Used extensively for shop interior fitting.

"VERILUX."
Recommended where a light having a colour value near to that of daylight is required. Made of compound glass, built up of three layers clear glass, opal and blue, which absorbs the red and yellow rays, producing a white light.

"UNALUX."
The enclosed unit with the satin finish, entirely dust-proof. Ideal for large offices, restaurants and public buildings of all kinds.

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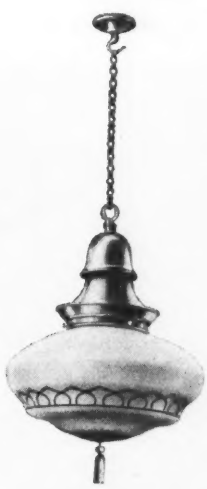
A cased glass with egg-shell finish, used extensively for school and railway-carriage lighting.

F.C. 10172
"VERILUX"
Pendant containing three layers of glass—opal, clear and blue.

F.C. 8929
"BRITALUX"
Dust-proof lighting unit with low light-absorption glassware.

G. 100/6
"SUPERLUX"
Fitting: Cased glass, with egg-shell finish.



F. 1557/8
"UNALUX"
Dust-proof lighting unit combining efficient light distribution and artistic appearance.

The services of G.E.C. Designers and Illuminating Engineers are offered **free** to all concerned with lighting problems. Experts will give information, make suggestions, or prepare complete lighting schemes without obligation.

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Branches throughout Great Britain and in all the principal markets of the world.

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Ideal Cooking and Lighting Equipment

On this and the following page are views of the kitchen, service room and dining and dancing hall of the administrative and clerical staff of a large London business concern which has taken a great interest in the cause of Smoke Abatement, and has thus helped directly and indirectly to increase the hours of sunshine in the metropolis. In the kitchen all cooking appliances used are absolutely smokeless. They are designed and finished on lines which make it possible to keep them perfectly clean with a minimum of labour, and to maintain a quick and punctual service. They are solidly constructed, and will have a life of many years without loss of efficiency.

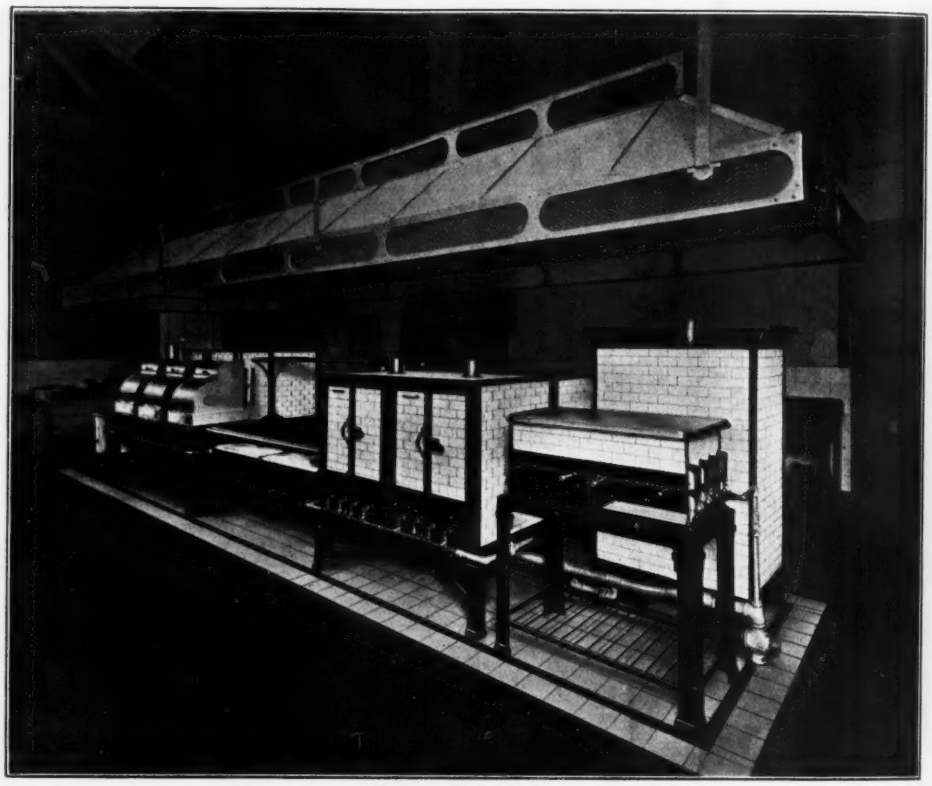


FIG. 1.—View of one side of the central battery of modern gas appliances which cook meals for the administrative and clerical staff of a large London business concern. This kitchen is also used to cater for social events connected with welfare work and sports organizations. The appliances shown consist of a three-pan fish-fryer, a double hot-plate, a confectioner's oven, and a double grill, all surmounted by a hood of angle iron and wired glass.

FIG. 2.—The other side of the central battery of cooking appliances, showing two large gas roasters, a double hot-plate, three automatic gas steamers and three 12-gallon vegetable boilers. The interiors and exteriors of the appliances are enamelled to facilitate cleaning operations. The kitchen is perfectly lighted by four 6-light semi-indirect gas-lighting pendants of the type shown in Fig. 3. These are turned on and off by distance control cocks.

for Staff Kitchen and Dining Hall

The lighting of the kitchen, service room and dining and dancing hall shown on this and the previous page is also by gas. In the kitchen and service room fittings of the semi-indirect type have been provided, and give a steady light which is entirely free from glare. Pendants and brackets with silk shades of dignified design make the dining and dancing hall one of the most beautifully lighted rooms in London. All lighting fittings are turned on and off by distance control cocks fixed in convenient positions. Full-course dinners cooked in the kitchen have been provided for no less than 300 people in one day, and the largest meal served at one time consisted of 600 suppers.

FIG. 3.—The service room is situated on a level with the dining hall to be seen in Fig. 4. The all-gas kitchen shown on the previous page is on the top floor of the building, and six lifts convey the cooked food down to the service room, which is equipped with an instantaneous gas water-heater for tea-making, four coffee and milk urns, and a long gas-heated hot closet, and carving table with bain-marie. The service room is lighted by four 6-light semi-indirect gas-lighting fittings.

FIG. 4.—Each of the ten pendants in the dining and dancing hall has a 7-light superheater cluster gas burner, lighted and extinguished by a distance control cock. On the walls are fourteen 2-arm gas brackets, which are turned on and off in pairs by distance control devices. The pendants and brackets are shaded with silk of an orange colour, which imparts a pleasant mellow glow to the room. The average numbers of lunches and teas served daily in this room are respectively 280 and 200.

The Floodlighting of War Memorials

WHERE war and other memorials take the form of statues, columns, or arches, it is is becoming more and more the practice to provide for their illumination by night, with the result that many of these memorials are actually more noticeable at night than they are during the daytime. With very few exceptions the system of illumination adopted is floodlighting, which has many advantages over any other method. Floodlighting can be arranged to illuminate uniformly the entire surface of the memorial, and to make it stand out in bold relief against the dark background of the night sky. Further, floodlighting enables the source of light to be placed at a distance from the object to be illuminated and to be easily concealed from view, so that the effect of the lighting is not spoiled by the glare of powerful lamps in the immediate vicinity.

The British Thomson-Houston Co. Ltd. have carried out many such installations, of which a recent example is the Sunderland War Memorial. The lighting of this memorial and its surroundings is of particular interest because it was undertaken by the Sunderland Electricity Department at their own expense, to mark the completion of the laying of over sixty miles of cable network and the changing over of the public street lighting from gas to electricity.

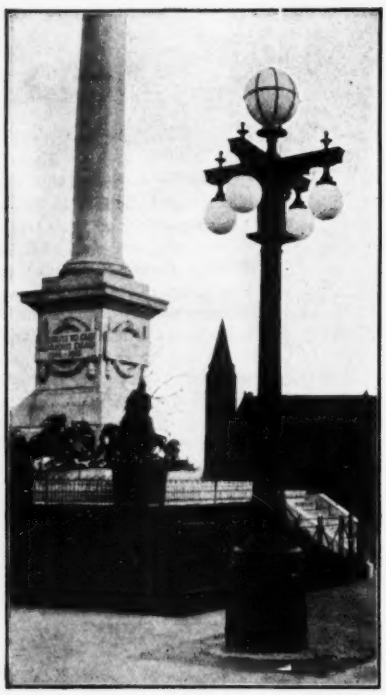


FIG. 1.—Sunderland War Memorial. The standard shown in the foreground serves the dual purpose of supporting a Floodlight Projector (concealed in the spherical lantern at the top) and also four Alabas lanterns which illuminate the promenade. There are four of these standards.

The floodlighting installation consists of four B.T.H. type 883/B projectors, each fitted with 500-watt Mazda gas-filled projector lamps.

The projectors are concealed from view, being contained in special decorative spherical lanterns mounted well above head level on top of ornamental standards. The standards are situated opposite the four corners of the base of the column.

For lighting the promenade around the memorial four B.T.H. Alabas lanterns, fitted with 200-watt Mazda gasfilled lamps, are also mounted on each of the standards supporting the floodlight projectors.

The spectacular effect of the whole installation is excellent, and it is probably one of the best examples of floodlighting of memorials to be found in the country.

FIG. 2.—Sunderland War Memorial by night.

Gas Lighting

Importance of the Lighting Load

In the address of Mr. C. Valon Bennett, President of the Southern Association of Gas Engineers and Managers, delivered at the annual meeting on March 28th, he emphasized the importance of the lighting load to the gas industry. He remarked: "We are all quite sure that the gas industry, instead of being a dying one, is only just commencing to reach manhood, and therefore it is not only up to us to see that gas is used in increasing quantities for purposes not contemplated a few years ago, but it is essential that we make a sustained effort to retain the business which has been ours for ages —and I refer particularly to the lighting load. I have met gas engineers who seem quite resigned to the possibility that gas lighting is eventually bound to be superseded by electricity, but I cannot help thinking such gentlemen do not fully realize what they would lose in output if such a state of affairs actually came about."

As an example he took the case of coin-meter installations, showing that in his district the sales in this class of installation would drop by 18.7 per cent. if no gas were used for lighting.

Turning next to public lighting, he pointed out the opportunities that exist, and the necessity of keeping gas-lighting installations thoroughly up to date.

"In many areas the work of lighting the various thoroughfares is entrusted to the local gas undertaking, and I must admit that in a large majority of cases the work is carried out exceedingly well; but there are still too many districts where there is much room for vast improvement. I realize that the numbers and positions of lamps are usually decided upon by persons other than those who have made a study of illumination, but, even so, there cannot possibly be a legitimate reason why the service which the local authorities have the right to expect, and the gas undertaking should be pleased to provide, is lacking.

For some years past, I have paid particular attention to public lighting in the various districts through which I have travelled, and in more cases than I care to think of the state of affairs is not as it should be.

It has been stated over and over again that public lighting does not pay; but I yet fail to see why it should be an expense, and I feel certain it can always bear, if not a direct profit, certainly an indirect one, provided the matter is dealt with properly. Street lighting should be one of our best advertisements, and it will be so if it is of such a character as to create a good impression in the minds of those who use the roads at night. If, on the other hand, the lighting is bad or the apparatus in wretched condition, the impression made will be that the local gas undertaking is asleep in all matters; and it supports the erroneous idea that gas lighting is a thing of the past."

The Manufacture and Properties of Glass and their Application to Illuminating Engineering

By S. ENGLISH, D.Sc., F.I.C., F.Inst.P.

DISCUSSION

(*Continued from page* 140.)

THE CHAIRMAN (Mr. C. C. Paterson) said that Dr. English was to be congratulated on having dealt with a very wide subject and covered the ground so lucidly in so short a time. He would ask Professor Turner, one of their distinguished visitors, to open the discussion.

Professor W. E. S. TURNER (Secretary of the Society of Glass Technology) said that he counted it a very special privilege to be asked to open the discussion on his first appearance at a meeting of the Society. He would have been well content to sit in a corner to learn something of its procedure. He thought that the privilege had been extended to him because he had had a long connection with Dr. English as a colleague. The connection had recently been broken, and although he regretted the break he was glad that the seconding of Dr. English to the Department of Illuminating Engineering would strengthen both the branch of illuminating engineering and of glass manufacture, of the general principles of which he had a thorough knowledge. He congratulated the author of the paper on the lucid way in which he had presented the subject and on the range covered.

His remarks would be only of a general and non-controversial character. In the first place he would like to say that of the four main groups into which glasses might conveniently be divided, especially with respect to chronological order of development, were glasses for artistic purposes, glasses for containers (drinking glasses in particular), glasses for the transmission of light, and a fourth class—not very clearly defined yet but most important—namely, glasses for general scientific purposes. Really the last group, whilst clearly understood, had widespreading boundaries, nowadays overlapping the other groups. If he were asked to express an opinion as to which of these groups the greatest possible interest was being taken in at the moment he would say without hesitation the group of glasses for illuminating purposes. This group included sheet glass of all kinds, in the manufacture of which new processes were of very recent development, as well as electric light bulbs manufactured not only by the wonderful Westlake machine, but also within the last year in America by a machine as yet little known and still more wonderful in its productivity. In this field of glasses for illuminating purposes no study was more fascinating than that which concerned the transmission of special radiations. Thus there was a type of glass, such as that utilized by Professor R. K. Wood during the war for naval signal purposes, glass which transmitted light only in the ultra-violet, and the utilization of which required the use of a fluorescent screen by the receiver. Then again, we had glasses like the Calorex glass, produced by Messrs. Chance Brothers, which absorbed the heat rays, and in summer kept rooms glazed with it at a very comfortably cool temperature on hot sunny days. Finally, in a long list of such glasses he would direct attention to the new forms of ultra-violet ray-transmitting window glass, the first of which, discovered by Mr. F. E. Lamplough and made by Messrs. Chance Brothers, was a marked British success. Dr. English, in his paper, had made no reference to these glasses, but possibly if time permitted he (Dr. English) might be prepared to say a word or two about them.

He would like to congratulate Dr. English's firm on the attempts they were making to produce illuminating glassware with an iron oxide content as low as 0.02 per cent. This was really an astonishing feat. The determination to make glass of this quality was entirely praiseworthy, and in the right direction of progress. He (Professor Turner) had had the privilege of knowing something of the policy of the firm in this connection, but had not previously heard of their latest success in this direction. The presence of iron oxide was the cause of much trouble. Far and away the best plan was to do away with any problem of decolorizing by removing the source of the trouble, namely, the iron oxide. In conclusion, he would like to congratulate Dr. English on his splendid paper, to congratulate his firm and to offer his thanks to the Illuminating Engineering Society for their courteous welcome to him.

Dr. W. M. HAMPTON said that Dr. English had largely disarmed criticism by his opening statement that his paper consisted of a summary of well-authenticated facts. There were, however, one or two points to which he would like to refer after adding his quota to Professor Turner's thanks to Dr. English for his paper.

Dr. English gave the figure of 0.3 to 0.6 per cent. per cm. of light absorbed by the best optical glass. These figures were, he thought, rather optimistic, and reference to Mr. W. D. Haigh's paper, which was read before the Optical Convention, 1926, indicated that the lowest value he had obtained was 0.4 per cent. per cm., and that this had only been obtained for the most transparent region of the most transparent glass measured. In general, the absorption was nearer to 1 per cent. per cm. It needed a glassmaker to appreciate what an achievement it had been to reduce the iron oxide content in an ordinary commercial glass to a figure as low as .02 per cent., and he thought that congratulations were due to Dr. English and his company for their success in this direction.

On the subject of fading of daylight glass, he noticed that Dr. English did not express any definite opinion. He had had to examine a number of specimens which had been returned from time to time with the suggestion that the colour had faded. He might say right away that he had never found this to be the case. It should be remembered that in manufacture it was always necessary to have a certain working tolerance as regards thickness, and it might be taken that the method adopted for the manufacture of daylight glass did not allow an accuracy greater than $\pm .2$ mm. to be obtained. What had happened was that one of the pieces which happened to be rather on the thin side had been broken and had to be replaced by one slightly thicker, and, since very few people outside the industry realized how rapidly the colour changed with the change of thickness, the difference in tint had been put down to fading.

He would like again to thank Dr. English for the extremely valuable paper he had given, and the lucid manner in which it had been delivered.

Mr. B. P. DUDDING wished to associate himself with those who congratulated Dr. English on this paper.

Criticism on the ground of omission of relevant matter was ruled out, because, as the author had said, it was impossible where time was so limited to bring to notice everything of importance even in a paper limited to the subject of glass used by illuminating engineers.

There was one point that was not quite clear, and with regard to which misunderstanding might arise. The paper suggested that the shape of the particles in fluoride opal glass and phosphate opal glass was

fundamentally different. The speaker thought that that was not so, but that the function of the particles in either glass was not very different. Whether the particles were spherical or not depended on the glass composition and the method of working. Fluoride opals could be produced having spherical particles; and, on the contrary, phosphate opals might have non-spherical crystalline particles. With regard to diffusing and absorbing characteristics of opal glass, it has been shown by Ryde and Yates* that the diffusing properties of the particle was a maximum at a diameter of about 1.2μ. Further, they have shown that the absorption was also a function of particle size. If it were possible to determine a polar diagram for the light distributed round the small particle it would be found to be nearly uniform when the particle had a diameter of about 0.2μ, whilst with the larger particles most of the light is scattered in a forward direction. The high absorption associated with very small particles was due to the fact that the back-scattered light must travel through a greater thickness of glass before it finally emerged. With the glass adjusted so that the particles had a diameter of about 1.2μ, lamp bulbs could be made in which the diffusion was perfect and the absorption losses as low as 6 to 10 per cent.

Of the characteristics of glass which were not dealt with in the paper there is one which is of considerable importance to illuminating engineers, namely, the behaviour of glass towards atmospheric conditions. The deterioration of glass surfaces exposed to atmospheric influences varies enormously, depending on the glass composition. In hot climates and humid atmospheres, and particularly in towns where alkali or acid fumes might exist, it was possible to have serious deterioration due to chemical action unless the composition of the glass was chosen to avoid it. Lastly, turning to the question of the loss of light due to frosting, experiments in the laboratories of the G.E.C. at Wembley confirmed the low figure of 1 to 1½ per cent. for internally frosted bulbs when the filament was centrally placed in the bulb. It was important to note that the position of the filament influenced the losses obtained. This was due to the influence the angle of incidence of the light on the small facets of the frosted surface had on the total length of path traversed in the glass.

Dr. English commented on the necessity for "fortification" of etched surfaces, but recent work in America suggested that all heavily etched glass was brittle when the impact was applied from the side opposite to that etched, and that therefore the practical difference between the externally and internally frosted bulbs was solely due to the conditions under which they were likely to receive impact.

Dr. J. W. T. WALSH entirely associated himself with what had been said about the high quality of the paper and with the congratulations offered to its author. If any proof were needed of the interest which the subject was creating at the present time the number present that evening would supply it. The reason why it had not received adequate attention in books on illuminating engineering was that illuminating engineers feared to rush in where even an angel like Dr. English found it difficult to tread, and they therefore kept away from it when writing.

He was interested in glass, particularly as it was used in photometry. It seemed fairly simple to get colourless glass, i.e., glass that would transmit almost equally through the spectrum so long as the transmission was not too low. If one wanted to get a glass that would only transmit a tenth or a hundredth of the light he was in difficulties at once. Glassmakers would do a great service if they could produce a really good neutral glass with a low transmission, but perhaps that was impossible.

He was a little worried by the remarks in the paper about artificial daylight glass. He was interested in that kind of glass, but he was still more interested in a blue glass which would change the colour of the light from a vacuum lamp to a sensation match with that given by a gasfilled lamp. He did not know whether there was any hope of getting a bluish glass which would produce a sensation match and maintain its transmission factor to the highest degree of accuracy.

He was very surprised indeed to hear it suggested that daylight glasses could only be produced commercially to an accuracy of thickness of the order of ± 10 per cent. He began to wonder whether the curves of transmission of artificial daylight that had been shown on screens during the last year or two were really worth the glass that they were written on.

Mr. HAYDN T. HARRISON said that the paper was most valuable as there were very few available on the subject, which was of considerable importance. The illuminating properties of glass had been to a certain extent a mystery hitherto, as nobody had previously provided definite information on the subject, but thanks to Dr. English there was now considerable data to go on.

He found great difficulty in reading the literature and studying data on glass because the units used were confusing. He noted that Dr. English measured diameter of particles and other things in terms of μ. He hoped he did not use the same unit for defining the length or distance of everything!

With regard to absorption and transmission, the first table spoke of absorption. Dr. English had rightly pointed out that 8 or 9 per cent. was often accounted for by reflection (Fresnel's formula). Did the absorption factors given in this table allow for light not transmitted due to reflection, and thus make it comparable with the previous statement that with the best European optical glass the absorption was generally between 0.3 and 0.6 per cent. of the incident light per centimetre? The table did not state the thickness of the glass except in the case of the Jena milk glass (massive 2 mm.). Did the other factors apply to glass 1 mm. thick?

In a later table the absorption factor was replaced by a transmission factor rising to a maximum of 0.858 and falling to 0.515, which he concluded would mean an absorption of 14.2 per cent. and 48.5 per cent. respectively. Did these include any losses due to reflection?

The term "scattering power" was used, and Schott's suggested formula for efficiency including scattering power and absorption was cited, but before it was possible to use such a formula it was necessary to define "scattering power." Was it another word for diffusion?

The confusion of units and lack of clear definitions as to the meaning of each detracted largely from the value of useful papers such as that put forward by Dr. English; therefore he sincerely hoped that B.E.S.A. would soon issue some clear definitions of the meaning of the various factors it was necessary to use when discussing a subject of such importance.

Mr. E. A. HAILWOOD also wished to express thanks to Dr. English. Glass manufacturers frequently found themselves up against difficulties, and were sometimes at a loss to know how to get over them. The paper had shown the complexity of the subject, and he felt that this should enlist a little sympathy with those who had to deal with these problems. In many cases tests were carried out under conditions where a very little variation made a great difference in the result. Many experiments were made with glass in plate form, and it was difficult to get anything like a uniform thickness. The whole subject included much that was mysterious, even to glassmakers. They tried to utilize in their work the latest instruments and to attain the greatest possible uniformity, but variations did occur. Such variations might be occasioned by many different factors, such as a change of the direction of the wind, altering the pull of the chimney, or affecting one side of the furnace more than the other, the influence of fog, etc. After what Dr. English had said perhaps the difficulties which the glassmaker had to contend with in order to meet requirements would be realized.

With regard to opal glass he often wondered what harm the red effect really did, because, after all, people were not looking directly at the glass; and, even so, he did not know that the red was in itself objectionable. In regard to changes of colour, it had taken 80 years, in the instance brought before the meeting of the station

* Journal of Society of Glass Technology. Vol. 10, p. 274, 1926.

roof glass, for it to change from an almost colourless condition to a slight purple. Looking at the matter from the artistic point of view, naturally he thought that a little purple was an advantage. If he was looking up at a glass pavement he would sooner see purple than green, because in his opinion the effect was more pleasing and the absorption of light was less.

It was very difficult in mass production to get the particles the same size. There were various reasons for this. The temperature varied at different times of the day, and the furnace must be opened in order to draw the glass out. All such points had to be taken into consideration. He thought that the illuminating engineer should not ask for something which could only be obtained at an excessive cost. What was needed was something at a reasonable cost which would attract ordinary people. The effect of "rejects" and breakages might be either to dishearten the glassmaker altogether or to send the price of the article up so high that it would not sell. The result would be to defeat the object aimed at, and bring the ordinary citizen back to the ordinary globe. High cost was all very well for scientific purposes, but in dealing with glass for ordinary purposes of illumination the question must be considered from a practical point of view.

Mr. A BLOK could not let the opportunity of asking questions go by, although he felt somewhat damped by the robust common sense in some of the remarks of the last speaker. These certainly served as a reminder that in some of the matters under discussion a compromise had to be arrived at between one's natural desire for scientific accuracy and the harsh demands of commerce. He congratulated the author on the lecture and on the experiments which he had conducted, which showed the practised hand of the successful experimenter.

He had been very much interested in the extraordinary reduction in the iron content of glass. This clearly was a most remarkable performance, and without any desire to pry into manufacturers' arcana or to ask them to disclose their processes unduly, he asked for more information as to how this low figure was achieved. Was it a question of selecting raw materials, or one of treating the batch mixture chemically, or by other means? If it were possible by chemical or other means to get down to so low a figure as had been given, it seemed as if persisting in the course which had been pursued might ultimately remove the whole difficulty and render colour correction unnecessary. In this connection perhaps light could be thrown by Dr. English, possibly ultra-violet light—(laughter)—on the changes of colour which occurred in alabaster bowls. He was under the impression that a tinting, sometimes a yellow or sometimes a purple effect, took place in these bowls when in close proximity to gasfilled lamps.

It had been stated that when a bulb was etched internally it was found to be brittle until it was fortified. He had some difficulty in accepting the explanation that it depended on the direction of the impact, though it might be so. He did not know whether any microscopic examination had been made of a cross-section of the material of an acid-etched globe. Were the fissures of the same nature in the case of internal etching as in the case of external etching?

With regard to opal glass, he was inclined to agree with the previous speaker that in many cases it was perhaps not such a terrible thing even if a red outline of the filament were seen. What was the colour selectivity of the suspended particles themselves? Were they colourless or opaque? If they were neither the one nor the other, but translucent, would it be possible to choose suspended materials which would give colour-selective transmission? Greenish particles, for instance, floating in the colourless menstruum of the glass, might perhaps be arranged to prevent the red appearance of the filament.

Finally, he asked if the author of the paper could give any information on the weathering of those window glasses of high ultra-violet transmission which were coming into extended use. He had heard it alleged that these glasses, and particularly when used in urban positions, contracted a surface film which was difficult to remove. If this were true, was it peculiar to the substance of these glasses, and what would be the effect on the transmission of the short-wave light? In the case of quartz bulbs for mercury ultra-violet lamps some makers said that care must be taken to keep bulbs clean by washing them with alcohol or methylated spirit after handling them. Was that in order to remove surface dirt or organic substances which might be present in secretions from the skin of the operator's fingers? Was there any analogy between that which happened in these mercury tubes and that which might happen in the ultra-violet window glasses?

Mr. H. H. LONG asked, with regard to the two opals shown—one revealing the lamp filament and the other completely diffusing the light—whether the difference was due entirely to heat treatment, or to the chemical constitution of the glass, or to both. He also enquired whether any definite data were available regarding the correct process for obtaining this complete diffusion; the discovery was interesting and the data, if available, should be applied commercially.

Mr. W. G. RAFFÉ, A.R.C.A., said that an interesting point had occurred to him with regard to coloured glass. At the British Industries Fair he came across Pyrex glass, and was told that the use of different colours would seriously affect the coefficient of expansion and would not allow its use for oven wear. In dealing with artistic enamel work he had never come across any technically serious difference in the coefficient of expansion even when working with 40 different colours and as many "firings" on one sheet of metal.

Another interesting point was fracturing. A Birmingham firm had recently developed a material for building preservation based on the fact that the sandstone found near Edinburgh (Craigleith) weathered exceedingly well. He had made experiments, and had come to the conclusion that if he covered a bulb with a solution of free silica (i.e., non-alkaline) it would prevent any change of importance. With regard to fading due to sunlight, experiments had been conducted by the B.D.A. in Yorkshire and in India, and it had been found that the fading due to that cause was as much as, or greater, in Yorkshire than in India. It was thought to be due to humidity in addition to the impact of solar ultra-violet rays.

As an artist, he was not at all inclined to accept the idea that purple-tinted glass or greenish-tinted glass was sufficiently good to work by. He liked to get the purest white light possible and make for himself any change of the sort that he wanted.

Mr. E. STROUD said that they must all feel very much indebted to Dr. English for his exhaustive treatise on glass composition and manufacture. As Dr. English indicated, the nature and qualities of glass formed a very complex subject requiring very special study, and it was to the great advantage of illuminating engineers to have had this opportunity to explore some of the intricacies of a material so intimate with their work.

As regards the remark of one of the speakers that a slight tinge of pink colour in the glass was not objectionable, he had found that users of illuminating glassware were very discerning people and demanded clear and colourless glassware, and it was up to glass manufacturers to produce as perfect a material as possible.

As pointed out by Dr. English, the use of decolorizer in the glass composition when used under conditions of prolonged sunlight tends to change the original colour of the glassware. This happens chiefly with decolorized glassware exposed directly to the sun rays, as is the case with street-lighting units.

The firm with whom he was associated had devoted a great deal of research to this particular phenomenon, and were now able to eradicate this defect.

Mr. H. S. ALLPRESS said that he had heard it stated that decolorized glass showed dark bands in certain parts of the spectrum and could not therefore be used for spectroscopic work. He had never tested the transmission at different parts of the spectrum, but had detected, during photometrical work, that the total

absorption of decolorized glass was sometimes greater than glass of a greenish colour due to the presence of iron, and he had always assumed that this was due to a uniform absorption throughout the spectrum. A slide shown by Dr. English seemed to confirm this, but he would like to receive an authoritative statement he could repeat.

Mr. Allpress added that it was possibly a little strange that glass so decolorized should be strictly neutral and transmit a true white, as the white produced by mixing monochromatic green and purple light was only a sensation white and not a true spectral white. Therefore one would certainly not be surprised to see at least unevenness in the absorption curve of a medium containing a mixture of green and red colouring matter.

Mr. G. H. WILSON remarked that the figures for the percentage light absorbed by various glasses given in Table I raised the important question of the method of measurement of absorption figures and the relative importance of reflection, transmission and absorption factors in connection with the performance of diffusing fittings.

It was not stated in the paper by which method the figures given by Schott were obtained, and the following experimental results showed the different values which might be obtained by variations in the method of measurement. The readings taken on a totally enclosing low absorption opal glass globe showed the total loss of light to be 12 per cent. The same glass measured as a flat plate with a collimated beam of light incident normally on one side gave the following results:—

	Per cent.
Total percentage of incident light reflected	62
Total percentage of incident light transmitted	35
Total percentage of incident light absorbed	3

The absorption figures obtained by the two methods were therefore widely different, and in order that comparisons could be made between various glasses it was important to describe the method of test.

If it was desired only to compare the relative light output of totally enclosing globes this figure can be obtained by a single measurement on the fitting itself, giving a figure such as 12 per cent. above. If the glass was to be used for hemispheres or dishes the reflection and transmission factors were of importance when it was desired to estimate their performance.

There was one type of glass which he thought should be mentioned, as much development work has taken place upon it, and that was heat-resisting glass. The production of glasses having high softening points and low coefficients of expansion had provided the solution of such problems as condenser lenses having a very large angle of pick-up, and electric lamps with high wattage filaments in bulbs of small dimensions.

THE CHAIRMAN, in thanking the speakers, said that he was sure that there were others present who could have contributed usefully to the discussion of the subject which Dr. English had presented, and if so the Secretary would be glad if they would send in their remarks to him in writing.

Dr. ENGLISH then briefly replied to the discussion. An extended version of his remarks will be found below.

Mr. W. J. JONES (*communicated*). In the first place I should like to express my appreciation of Dr. English's paper, and in particular to thank him for the very clear and lucid way in which the address itself was delivered. Unfortunately, too few illuminating engineers have even the slightest knowledge regarding glass. Indeed, to the majority the whole subject is shrouded in mystery. This is largely due to the fact that the whole subject is so complex, and Dr. English's contribution is therefore all the more welcome.

It is not often realized what a tremendous amount of research is going on, but until comparatively recently the facts from the illuminating engineering point of view have been all too few. This undoubtedly accounts for the reason why writers of textbooks on the subject of lighting have neglected this very important phase.

There are two matters on which I should like to comment. They both concern diffusing glasses. In the first place I would refer you to Schott's proposed formula for expressing the efficiency of diffusing glassware. It appears to me that the formula given cannot be taken as a criterion of the goodness of diffusing glasses, since it expresses the efficiency in terms of two quantities which, as far as I am aware, may be entirely independent.

We certainly do not know, in any event from recent knowledge, that the absorption of a glass does not necessarily increase the scattering power, since the latter is largely a question (as Dr. English points out) of the particle size of the diffusing medium and the relative refractive indices of the glass and the separated material. It appears to me that the questions of scattering power of a glass and its absorption must be treated as separate entities.

Although, from a glassware manufacture point of view, the mechanism by which the scattering takes place is exceedingly important, to an illuminating engineer it is only the result which matters, and, therefore, while the coefficient of scattering involving particle size, etc., would be of value to the glass manufacturer and its estimation probably involve prolonged research, I would suggest that the illuminating engineer is only concerned with relative brightness at different angles.

Indeed, if research could be propagated to give the degree of diffusion in terms of brightness at different angles on samples of glassware which are considered satisfactory, we should then be able to have valuable data for lighting-design purposes. I do not wish to deprecate the importance of the fundamental research, but making available such data as I have suggested above would greatly ease the situation as far as illuminating engineers are concerned.

The second point, which was so ably dealt with by Dr. English, was the cause for fragility in opal glass, and I think the fact to my knowledge that this difficulty is not serious in electric glassware reflects great credit on the manufacturers as a whole. I make this remark because the difficulty appears to be more apparent than real.

THE CHAIRMAN said that on being invited to be the guests of Holophane Limited they had expected good things, and certainly they had not been disappointed. The paper and discussion had been a very helpful one, and the evening had been amongst the best that he remembered in connection with the Illuminating Engineering Society. The audience had already expressed by applause its appreciation of the trouble which Dr. English had taken, but he would nevertheless move a formal vote of thanks to him. He would also include in the vote of thanks to Dr. English thanks to his colleagues in the Holophane Company and to the company itself, for their hospitality and reception of the Illuminating Engineering Society at their showrooms.

Dr. S. ENGLISH, in reply: I wish to thank the members present for the reception given to my paper, and the various speakers for their generous remarks, especially those of our "Glass" friends who have added further information concerning various points. I especially wish to thank Dr. Turner for opening the discussion and for the contribution he has made. The only point calling for comment in Dr. Turner's remarks is that dealing with ultra-violet ray transmitting glasses. As Dr. Turner knows, I have been busy on this problem for some long while, and have evolved a very satisfactory glass for this purpose, but since in this paper I wished to confine myself to a few points of particular interest to illuminating engineers dealing with artificial sources of light, it was not possible to include any data concerning this glass.

I am glad Dr. Hampton was able to give figures for the absorption of the best quality of optical glass, and to see that his figure of 0.4 per cent. per cm. was so close to those quoted by me. I am also glad that Dr. Hampton has been able to explain the apparent fading of daylight glass, and I appreciate that the difference in thickness on passing from one sheet to another is

bound to give a difference in the light-correcting power of such glasses.

I am indebted to Mr. Dudding for pointing out a matter in which a misunderstanding might arise, namely, the shape of the particles of fluoride opal glass and in phosphate opals. I agree with him that in both kinds of opals the particles normally are spherical, but at the same time I think it is more difficult to maintain a spherical shape of the particles in fluoride opals than it is in phosphate opals.

Regarding the question of deterioration of glass surfaces when exposed to atmospheric influences, I appreciate the importance of this point, and as a matter of fact it is now about 10 years since I published, as part author, a paper on the durability of glass, and quite recently I have been busy on this same subject again, but, as pointed out in my introduction, only a few selected subjects could be dealt with within the limits of one paper. If the Illuminating Engineering Society does me the honour of asking me to give them another paper on the subject of glass for illuminating purposes, I should include in that survey as one of the subjects for discussion the question of resistance to atmospheric corrosion.

When Dr. Walsh asks for a glass which will transmit a tenth or a hundredth of the light incident on it, and at the same time transmit uniformly throughout the spectrum, he is asking a great deal, especially when one remembers that the only way a glass manufacturer has of cutting down the transmission of glass is by introducing colouring oxides. The solution of the problem lies in the possibility of finding two, or more likely three, four or five colouring oxides, which, when added to a glass in correct proportions, neutralize the colour given by one another, thus producing an apparently dark grey glass. If research on this point were financed, no doubt a fairly satisfactory glass could be obtained, but when it is considered that in all probability four colouring oxides would be necessary it will be appreciated that an enormous number of meltings must be carried out before a satisfactory solution is obtained, and therefore the research would prove of a fairly costly nature. To a manufacturer the prospect is not attractive, especially in view of the fact that only a very small quantity of glass would be required to fill the needs of people interested in photometry.

The possibility of obtaining a blue glass to change the colour of the light from a vacuum lamp to a sensation match with that given by a gasfilled lamp is a much easier proposition, and I can see no great difficulty in obtaining such a glass provided it were worth while for a suitable manufacturer to take it up.

Replying to the points raised by Mr. Haydn Harrison, the absorption figures quoted in Table I do not include reflected light; as a matter of fact all the way through the paper absorption, reflection and transmission have been treated as distinct and separate factors.

Regarding the thicknesses of the glasses of which the absorption is quoted, these were not given in the original paper except that the flashings were marked "thick" and "thin"; apart from this it appears safe to assume that the thicknesses of the glasses were such as are used in ordinary illuminating glassware.

In Table II, where the transmissions of various glasses are quoted, the difference between 100 per cent. and the figure mentioned is naturally made up of reflected and absorbed light, so from this table it is only possible to get an estimate of the sum of these two factors. Regarding the terms "scattering power" and "diffusion," it must be admitted that at the present time, though these terms are synonymous, they are both used in a loose manner, merely due to the fact that there is no definitely accepted method of measuring them. A panel of a B.E.S.A. Committee is already busy on this particular problem, and it is hoped as a result of its labours that something quite definite regarding the measurement and definition of the diffusing properties of glass will materialize.

I am glad that Mr. Hailwood has mentioned some of the difficulties which are met with in the actual manufacture of glass. Every one that he has mentioned is a serious practical difficulty which often arises, and I can assure members of the Illuminating Engineering Society that many more difficulties arise in glass manufacture than are dreamt of by anyone outside a glass house. If this paper has helped illuminating engineers to appreciate some of these difficulties, one of its aims will have been accomplished.

Mr. Blok appears to be afraid that in one of his questions he asks too much, but I can assure him that I have no hesitation at all in giving him the information for which he asks concerning the reduction of the iron oxide content in glass. This has been accomplished not by chemical treatment of the raw materials, but by a very careful choice of every one of the materials going into the glass, and by extraordinary care to preserve the original standard of purity throughout the whole manufacturing process. This in itself means an increase in cost of the glass, and I am afraid that any attempt to reduce the iron oxide still further by chemical means would make the cost prohibitive.

Regarding the changes of colour in alabaster bowls, it is reasonable to suppose that these changes in colour are caused by the influence of light on the constituents of the bowl, and according to the nature of these constituents the colour may change in exactly the same way as that mentioned in the case of street-lighting glassware, referred to in the paper. In this glass it has been found that the light from strong electric lamps, coupled with the temperature developed by such lamps, is often quite sufficient to develop either a manganese-purple colour or selenium-yellow colour if either of these materials has been added to the glass.

Regarding the fragility of etched glass, there is no essential difference in the nature of the etching on the inside and on the outside of the bulbs, provided that they are both done with similar etching solutions, but I think Mr. Blok will have no difficulty in appreciating the difference in strength between the internal and external etched bulbs if he looks upon the fissures produced by coarse etching as somewhat similar to diamond cuts in the surface of a piece of sheet glass. Any bending of the glass tending to open the cuts, as by a blow on the smooth side, causes fracture, whereas a blow on the etched side, bending the glass in such a direction as to close the cuts, does not cause fracture.

In opal glasses the particles do not show any selective absorption; their diffusing property depends entirely on reflection from, and refraction through, transparent particles. However, in the case of certain other glasses, for example glasses of the ruby class (in which the colours are produced by selective absorption of colloidal particles), it is possible to produce different colours by varying the heat treatment to which the glass is submitted, and thus varying the size of the particles. In fact great difficulty is experienced in maintaining uniformity of colour in such glasses.

Replying to Mr. Blok's question concerning ultra-violet ray transmitting window glasses, since, as already mentioned, I am in some measure responsible for a glass of this type—Holviglass—which is being

developed by the Holophane Company, I prefer not to comment on this point except to say that Holviglass is extraordinarily resistent to atmospheric influences, and that so far as our exposure tests go it is permanently transparent to all the wavelengths found in the ultra-violet portion of the sun's spectrum. As regards the loss of efficiency of quartz mercury-vapour lamps in the very short-wave ultra-violet region, this is admitted by the manufacturers, and is due to a change from glassy silica to tridymite, one of its crystalline forms.

Replying to Mr. Long, the difference between the satisfactory and unsatisfactory opal glasses shown is due both to composition and to heat treatment. The heat treatment must be such as to promote particle growth to the required size, but this is much easier with glasses of certain compositions than with others. To take one example only, although in ordinary opals it has been shown that only sodium and calcium fluorides separate out as the second phase, still to get a satisfactory opal it has been found essential to have a certain minimum proportion of aluminium present.

Mr. Raffé, when discussing the possibility of colouring cooking glassware, must have been talking to a salesman and not to a glass technologist. Rather more than a year ago I measured the expansion of certain colourless and strongly coloured glasses of similar compositions (apart from the colour) and found that the small proportion of colouring oxide which was necessary to give a deep colour had very little effect on the coefficient of expansion. Regarding the question of the fading of materials under different lights, quite a number of workers have published results on this subject, but up to the present no definite agreement appears to have been reached; for example, Luckiesh maintains that the fading is proportional to the intensity of the visible light, and is not due in any special manner to ultra-violet, whereas it is generally thought that fading is due to these rays.

Mr. Allpress is quite right in drawing the conclusion from curve No. 1 that glasses containing both iron oxide and manganese dioxide in correct proportions show a more or less uniform absorption throughout the spectrum, and not a banded spectrum as he had been informed. As a matter of fact, only a very few coloured glasses show any signs of a banded absorption spectrum. If Mr. Allpress examines Figure No. 1 again he will not wonder that the light transmitted by a perfectly decolourized glass is a true white, because the absorptions given by the colouring materials are not by any means monochromatic as his question suggests.

As mentioned when introducing the paper, I am well aware of the fact that the methods previously adopted for measuring the absorption of opal glasses were generally not as precise as they might have been, and I was also aware of more precise experimental results which had not been published, since this information was confidential and I was not in a position to include it in the paper. I am very glad, however, that Mr. Wilson has been able to give us some results. I am sure that illuminating engineers will be glad when the whole of the results of this particular research are available. As regards the heat-resisting properties of glasses mentioned by Mr. Wilson, this again is one of the points which unfortunately had to be omitted because of time and space considerations.

I agree with Mr. Jones that Schott's formula for the determining of the quality of diffusing glassware is defective both in its form and in so far as no method of measuring the diffusing power is stated. I also agree with him that what the illuminating engineer wants, at any rate as a first instalment, is the setting up of a recognized standard of the quality of diffusing glassware, probably by a measure of its brightness at different angles.

Daylight, Artificial Light and Artificial Daylight

Their Merits and Drawbacks

A MEETING of the Illuminating Engineering Society was held in the Lecture Theatre of the Home Office Industrial Museum, at 6 p.m., on Tuesday, April 24th, Mr. D. R. WILSON (President) in the chair.

On the arrival of members light refreshments were provided in the basement, and an opportunity was afforded for the inspection of the Lighting Section of the Museum, to which reference has previously been made.

After the members had assembled in the Lecture Theatre the HON. SECRETARY read out the names of the following applicants for membership:—

Ordinary Members—

Smith, C. A. .....Illuminating Engineer, Edison-Swan Electric Co. Ltd., 12, Welwood Road, Addiscombe.

Woodward, C. H. ....Borough Electrical Engineer, Albert's House, King's Park, Bournemouth.

Associates—

Sharma, R. M. .....Manager, Allies Electric Co., Johri Bazar, Agra, India.

Sustaining Members—

Messrs. Geo. Davidson & Co., Teams Glass Works, Newcastle-on-Tyne. (*Representative:* Mr. Thomas Davidson.)

The names of applicants presented at the last meeting were read again, and these gentlemen were formally declared members of the Society.*

The Chairman then called upon Mr. J. S. DOW to open the discussion on "Daylight, Artificial Light and Artificial Daylight; their Merits and Drawbacks."

Mr. Dow, in the early part of his address, pointed out the main differences in natural and artificial light, and raised the question how far it was desirable to imitate daylight by artificial means. Special attention was devoted to the problems involved in cases where a mixture of natural and artificial light is used. Some interesting experiments were performed to illustrate the effect of blue and red light on acuteness of vision, and the comparative influence of uncorrected artificial light and modified artificial daylight was considered.

Interesting exhibits were arranged by Capt. E. J. HALSTEAD HANBY and Dr. S. ENGLISH, and an interesting discussion ensued in which Mr. C. C. PATERSON, Mr. J. MACKENTIRE, Mr. L. E. BUCKELL, Mr. A. CUNNINGTON and Mr. W. C. RAFFÉ took part.

In conclusion, the CHAIRMAN, in moving a cordial vote of thanks to the author and exhibitors, expressed the appreciation of the Society of the privilege of holding this meeting in the Lecture Theatre of the Home Office Industrial Museum.

The Modern Reflecting Telescope

Professor G. W. Ritchey, who is delivering the Thomas Young Oration to the Optical Society this year, will take as his subject "The Modern Reflecting Telescope." The meeting is to be held at the Imperial College of Science and Technology (Imperial Institute Road, South Kensington), on Wednesday, May 16th, at 7-30 p.m.

The oration should be of considerable scientific interest. We understand that Professor Ritchey proposes to deal with two main types of telescopes, the fixed universal and the compact equatorial Ritchey-Chretien. He will also give an account of his experience in making and using the great telescopes of the Yerkes and Mount Wilson Observatories. An invitation has been kindly extended to members of the Illuminating Engineering Society to be present.

* April, 1928, p. 105.

TRADE NOTES & ANNOUNCEMENTS

THE "KANDEM QUARTERLY REVIEW."

We have just received the second number of this newly issued Review, which, like its predecessor, contains a variety of articles, and illustrates recent introductions of Messrs. Korting & Mathiesen Electrical Ltd. The present number is devoted mainly to street lighting. Special interest attaches to the new "Mirrorlite" lantern, which combines a prismatic reflector (metal-covered) with a ring of diffusing glass. The latter has the double effect of screening the lights and allowing a certain proportion of light to be emitted upwards and illuminate the surfaces of adjacent buildings.

Another article, entitled "The Psychological Aspect Appeal of Good Illumination," contains some effective pictures illustrating the importance of shadows. The Notes on Progress refer to several novelties, such as the "Kandem" straight-line fittings, and to the adoption of the "Dia-Carbone" long-burning flame arcs in Leipzig.

GOVERNMENT COMMISSION ON AUSTRALIAN RESOURCES.

Sir Hugo Hirst, Bt., Chairman of the General Electric Co. Ltd., has been appointed one of the four members of a Government Commission leaving for Australia in August to confer with the Commonwealth Government and the leaders of industry and commerce on the development of Australian resources, and on any other matter of mutual economic interest to Great Britain and the Commonwealth which would tend to the promotion of trade between the two countries and the increase of settlements in Australia. The other members of the Mission, as announced by Mr. Amery, Secretary for the Dominions, in the House of Commons on Monday, are Sir Harry McGowan, K.B.E., Sir Ernest Clark, K.C.B., and Mr. Donald Malcolm. It is expected that the Mission will remain in Australia about six months.

B.T.H. ENCLOSING FITTINGS.

A folder (L.422) issued by the British Thomson-Houston Co. Ltd. illustrates the progressive development in enclosed diffusing fittings, which are now available in quite a variety of shapes and designs. These fittings lend themselves well to decorative treatment, and they have the advantage of reducing deterioration due to dust to a minimum. The leaflet is attractively printed in a scheme of black and red, and copies may be obtained on application to the Company.

TRAFFIC SIGNAL LANTERNS.

It will be recalled that a variety of luminous traffic signs and signals were exhibited on the occasion of the paper read by Mr. W. J. Jones on this subject earlier this year.

A leaflet received from Messrs. Foster & Pullen Ltd., of Bradford, shows some good designs boldly executed and suitable for use with gas lanterns. Some examples of the superheater burners supplied by this firm are also included; these superheater burners have many advantages, and mark a great advance on the types available only a few years ago.

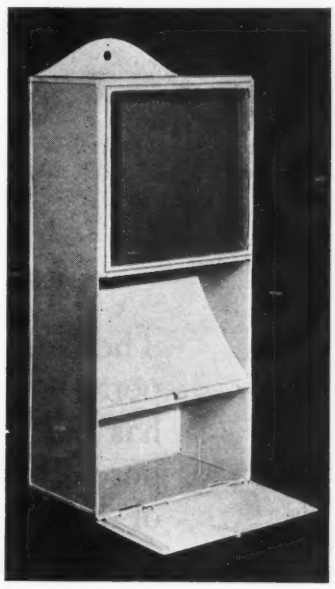
ELECTRIC FIXTURES.

Under this title an interesting list of fittings is supplied, issued by Woodfyt Sales Ltd., who are associated with the reproduction of fittings in wood of antique design. Generally speaking, a simple and dignified treatment is aimed at, and varieties of standards, wall lanterns, chandeliers, etc., all in wood, are illustrated.

Another list before us, from Messrs. Smith & Ansell, of Birmingham, deals mainly with metal fittings, and contains some pleasing illustrations in colour. Some of the semi-indirect types utilizing orange-coloured glassware may be mentioned as particularly attractive. At the end of the booklet particulars of portable units and accessories are also given.

REFLECTED-LIGHT SHAVING MIRRORS AND BATHROOM CABINETS.

Some useful types of reflected-light shaving mirrors are illustrated in the March issue of the "Osram G.E.C. Bulletin." The nature of this "Magnet" device will be understood from the accompanying illustration. By means of a lamp fitted at the rear of the mirror the latter is warmed sufficiently to make it immune from steam or mist, so that a clear mirror is always available.



The illumination of the face is also effected by the lamp concealed behind the back of the mirror, the rays of which are reflected upwards by means of a reflector of special curved design. The device has the great advantage that the person shaving is independent of all pendent lights, which in practice are not always placed in the most appropriate position, and may give rise to irritating shadows.

At the base of the apparatus there is a convenient locker for housing shaving requisites. The fitting is finished in white washable enamel, and has an opal glass shelf and a "Magnet" Bakelite non-tarnishable lampholder.

COLOURED GELATINES FOR STAGE LIGHTING.

As is well known, coloured gelatines now play an important part in stage lighting, and are also widely used in connection with coloured spot lighting in shop windows. For such work they have considerable advantages over the old method of applying lacquer to lamp bulbs, which is very liable to peel off under the action of heat. Another point is the great variety of shades of colours now available in gelatines of this description. This is brought to our notice by a compact little card containing various samples issued by the Strand Electric and Engineering Co. Ltd., who make a speciality of stage lighting. This little device, which can be readily inserted in the pocket, contains a series of samples each 1¼ inches square, and a great variety of shades is represented.

CONTRACTS CLOSED.

The following contracts are announced:—

METRO-VICK SUPPLIES LTD.:

London and North-Eastern Railway; for a period of 12 months for the supply of Met-Vick carbon, metal filament vacuum and gasfilled lamps.

Port of London Authority; for Met-Vick gasfilled lamps for the three months from April 1st, 1928.

SIEMENS ELECTRIC LAMPS AND SUPPLIES LTD.:

London and North-Eastern Railway; for 12 months' supply of Siemens electric lamps.

Port of London Authority; for three months' supply of Siemens vacuum electric lamps.

The Lighting Service Bureau

The accompanying illustration shows a view of a portion of one of the studios at the Bureau, which has been converted into three cubicles for the purpose of demonstrating the specialized application of lighting to shops, factories and schools.

Also available for demonstration are the most recent methods of lighting signs, posters, etc. The fullest data upon all lighting subjects is always available.

Lectures on any branch of electric lighting can be arranged by request.

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THE LIGHTING SERVICE BUREAU

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REVIEWS OF BOOKS AND PUBLICATIONS RECEIVED

THE EMPIRE MUNICIPAL DIRECTORY AND YEAR BOOK, 1928–29. (*Published by Municipal Engineering; pp.* 318+10; 11*s. post free.*)

The 46th edition of the above Directory is now before us. A foreword is contributed by Sir Henry Maybury. There is the usual complete series of lists of Corporations, Urban and Rural District Councils, etc., and their various officers—information which we understand could not be obtained in this complete form elsewhere, and the various sections are brought up to date. The subjects treated include Road Construction and Maintenance, Plain and Reinforced Concrete, Lighting, Heating and Ventilation, Water Supply, Sewage Disposal, Fire Prevention, Housing and Town Planning, etc., and the sections include a mass of information which should be exceedingly useful to municipal engineers and public health officers. An up-to-date item is the section devoted to Public Recreation Grounds, in which the construction of various types of hard tennis courts is briefly explained. In the section on Lighting reference is made to two recent developments—the extending use of illuminated direction signs and the curative effects of artificial sunlight. This Directory occupies a place of its own, and it should continue to prove helpful to all concerned with municipal engineering and kindred matters.

LEITFADEN DER LICHTTECHNIK, *by Prof. Dr.-Ing. W. Voege.* (*Julius Springer, Berlin,* 1928; *pp.* 80; *figs.* 47; *Mk.* 4.50.)

In the preface Dr. Voege explains that this little book had its origin in a series of lectures delivered by him in connection with a course initiated by the Hamburg Electricity Works. This course, which was intended mainly for electrical contractors, seems to have been framed on lines not unlike that developed by the E.L.M.A. Lighting Service Bureau in this country, but in its final form the book deals with general principles rather than detailed applications of light in detail. The initial chapters deal with photometric quantities, photometry and underlying physical principles. The section on photometry contains illustrations of several illumination photometers which are not very familiar in this country, though they are designed on lines similar to those of standard British types. Following these first three chapters there is a brief summary of sources of light, both gas and electric, a discussion of lighting fittings, and notes on interior and outside lighting. The recommendations of the German Illuminating Engineering Society on industrial lighting are reproduced, and the section on the planning of installations is commenced with a schedule of enquiries, to serve as a basis for specifications. There seems a need for a similar compact little book in this country.

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The Illuminating Engineer

The Journal of

GOOD LIGHTING

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SPECIAL INFORMATION.

THE ILLUMINATING ENGINEER (the Journal of GOOD LIGHTING) was founded in January, 1908, and has thus been in existence for twenty years.

SINCE the year 1909, when the Illuminating Engineering Society was founded in London, it has been the official organ of the Society.

IT is *the only journal in this country exclusively devoted to Lighting by all Illuminants.*

IT receives the assistance of contributors who are leading experts on illumination in this country and abroad. Foreign Notes and News will be a speciality, and correspondents have been appointed in all the chief cities of the world.

THE Journal contains *first-hand and authoritative information on all aspects of lighting;* it has also been improved and extended by the inclusion of a *Popular and Trade Section* containing special articles of interest to contractors, gas and electric supply companies, Government Departments and members of the Public.

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Good Lighting is of interest to everyone. The Journal is read by engineers, architects, medical men, factory inspectors, managers of factories, educational authorities, public lighting authorities, and large users of light of all kinds.

BESIDES being issued to all members of the Illuminating Engineering Society, the Journal has an independent circulation amongst people interested in lighting in all parts of the world. The new and extended form of the Journal should result in a continual and rapid increase in circulation.

Every reader of THE ILLUMINATING ENGINEER, the Journal of GOOD LIGHTING, *is interested in illumination, and is a possible purchaser of lamps and lighting appliances. Gas and Electricity Supply Undertakings likewise benefit by the movement for Better Lighting, with which the Journal is associated, and which stimulates the demand for all illuminants.*

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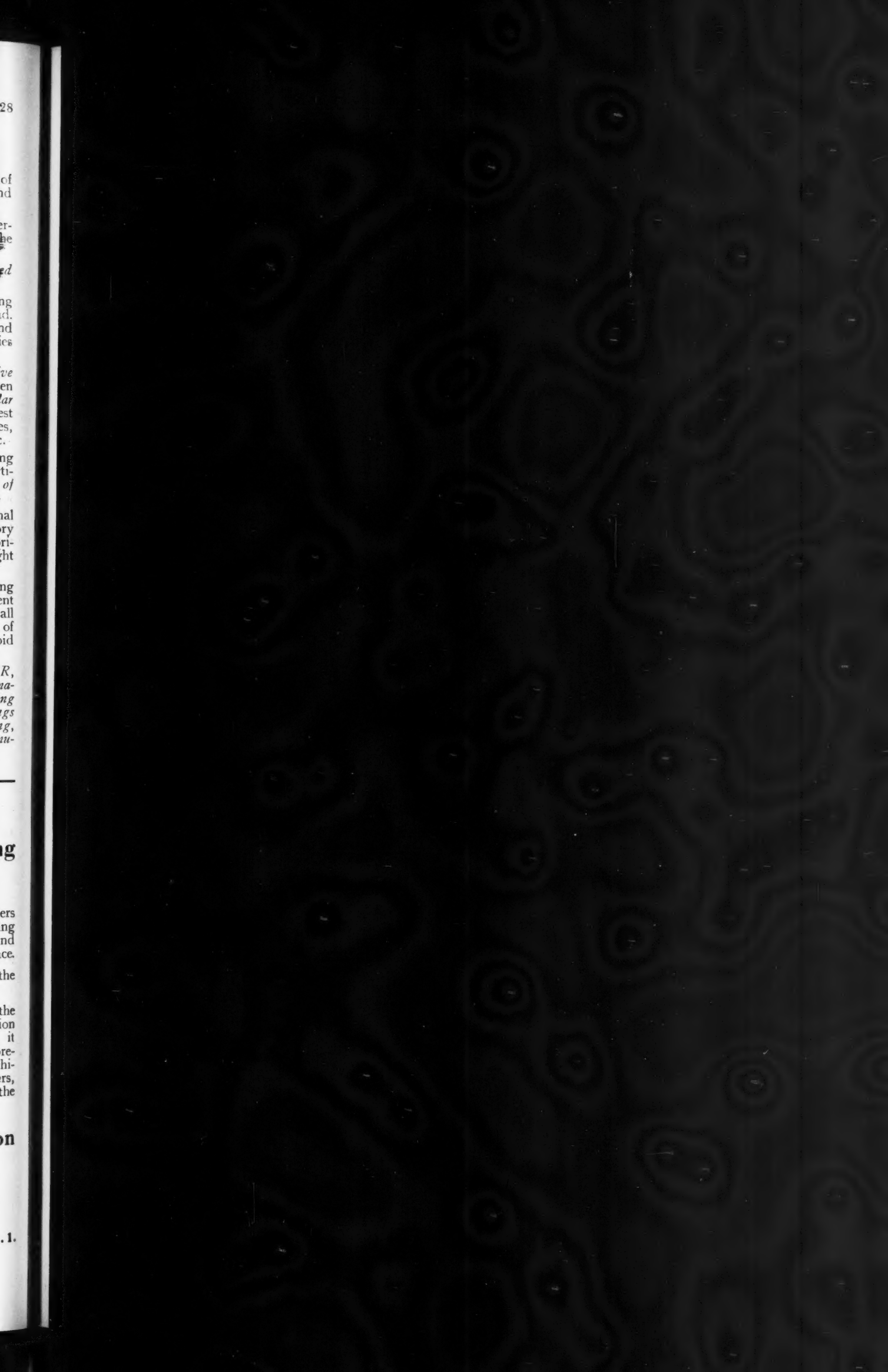
Members receive *The Illuminating Engineer*, the official organ of the Society, free.

The Society preserves an impartial platform for the discussion of all illuminants, and invites the co-operation both of experts on illumination and users of light; it includes amongst its members manufacturers, representatives of gas and electric supply companies, architects, medical men, factory inspectors, municipal officers, and many others interested in the use of light in the service of mankind.

The Centre for Information on Illumination.

For particulars apply to:

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